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AIR, PERMEABILITY OF COAL COMPACTS SUBJECTED TO COMPACTION PRESSURES OF UP TO 2,000 psi

FINAL REPORT

BY

WARNOCK HERSEY PROFESSIONAL SERVICES LTD.

MONTREAL, QUEBEC.

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AIR PERMEABILITY OF COAL COMPACTS

TERMS OF REFERENCE

The Geotechnical Research Centre of McGill University was sub-contracted by Mr. Daniel Champagne of Warnock Hersey to carry out the research programme as presented in Table 1. This program briefly presented in this table was the outcome of various discussions between the present author, Mr. Daniel Champagne and Dilip Desai (EMR) and differs from the original tender bidded on by Warnock Hersey in co-operation with the Geotechnical Research Centre of McGill University.

LIABILITY LIMITATION

The Geotechnical Research Centre of McGill University, its officers and personnel have used their best efforts to ensure that the data and results produced during the performance of these tests are as accurate as can be reasonably expected in the circumstances. However, the Geotechnical Research Centre of McGill University is a non-profit, service organization and it, its officers and personnel accept no responsibility for damages of any nature whatsoever arising out of the use and application of the data and the results by the Company or by other persons, nor in respect of special, indirect or consequential loss or any loss of anticipated revenue, or profits, whether or not the Geotechnical Research Centre of McGill University has been advised of the possibility of such a loss.

1. TESTING PROGRAM FORMAT

The test program undertaken by G.R.C. (Geotechnical Research Centre) is presented in brief in Table 1.

TABLE 1: AIR PERMEABILITY OF COAL COMPACTS TEST FORMAT

1. AIR PERMEABILITY

	Type of Coal	Test Condition	Number of Tests Attempted
(a)	fine	Incremental, small, 6 stress levels, Moisture content = As Is* + 10% and ∿15%	18
(b)	coarse	Incremental, small, 6 stress levels, Moisture content = As Is+, + 10% and ∿15%	18
(c)	fine	Duplication of (a)	18
(d)	coarse	Duplication of (b)	18
(e)	fine	Incremental, large, 6 stress levels, Moisture content = As Is*, + 10% and ∿15%	18
(f)	coarse	Incremental, large, 6 stress levels, Moisture content = As Is+, + 10% and ∿15%	18
(g)	fine	Single, small, 3 stress levels, Moisture content = As Is*, + 10% and ∿15%	9
(h)	coarse	Single, small, 3 stress levels, Moisture content = As Is+, + 10% and ∿15%	9
(i)	fine	Single, large, 3 stress levels, Moisture content = As Is*, + 10% and ∿15%	9
(j)	coarse	Single, large, 3 stress levels, Moisture content = As Is+, + 10% and ∿15%	9

This is a total attempted stress levels or tests of 144. The 6 stress levels referred to are 50, 100, 200, 500, 1000 and 2000 psi whereas the 3 stress levels are 100, 1000 and 2000 psi.

* The average 'as is' moisture content for fine coal is 30.2%.

\+ The average 'as is' moisture content for coarse coal is 36.2%.

Table 1 continued . . . .

2. *BLOW OUT TESTS*

Blow out tests were attempted on all 36 single level tests.

3. *BASIC MECHANICAL PROPERTIES OF COALS*

The following basic mechanical properties were also measured:

(a) compaction curve (dry density versus water content)

(b) specific gravity, and

(c) particle size distribution of compacted and non-compacted samples

---

2.0 BASIC MECHANICAL PROPERTIES OF COAL TYPES

In this section is presented the method and results obtained from the specific gravity, particle size distribution and compaction tests.

2.1 Compaction Tests

Standard compaction tests were carried out on both the fine and coarse coals. The procedure followed was for Method 'A', ASTM D-1557-70 as described for soils, except the following:

(1) the coal was not passed through a #4 sieve, i.e. the less than #4 sieve was not used, but instead a representative sample of each coal type was taken.

The procedure for method 'A' uses a 10 lb. hammer dropped through 18", with the application of 25 blows per layer on three layers.

The compaction curves obtained for the fine and coarse coals are

shown in Figures 1 and 2. As can be seen from these figures the optimum conditions of dry density and water content for the fine and coarse coals are 45.3 p.c.f., 70.5% and 46.8 p.c.f. and 69.2% respectively. For the insertion of the degree of saturation lines on the compaction curves, one is in a quandary. As previously discussed there are two values of G_s which can be inserted in the following relationship

$$S = \frac{G_s W \gamma_d}{(\gamma_w G_s - \gamma_d)}$$

in order to calculate the degree of saturation. Insertion of the average value of 1.24 for the apparent specific gravity would indicate that compaction can produce samples which are in excess of 100% saturation. Insertion of the value 1.644 (absolute) gives the more realistic saturation lines. This point clearly indicates that whilst compacting the coal using the hammer there is a considerable amount of degradation of the coal particles and that the absolute specific gravity more accurately mirrors the situation. Also, in the compaction—air permeability tests the most reasonable and logical data was obtained using the higher absolute specific gravity value.

2.2 Particle Size Analysis

In Figures 3 to 8 are presented the particle size distribution for the fine and coarse coals in the conditions of "as received", at 15% moisture and compactive stress = 2000 psi and at +10% moisture and compative stress = 2000 psi. The sieve analysis was carried out on oven dried coal using a dry sieving method through sieves #4, 12, 40, 60 100 and finally #200.

As can be seen from Figure 3, for the unstressed condition, 97%

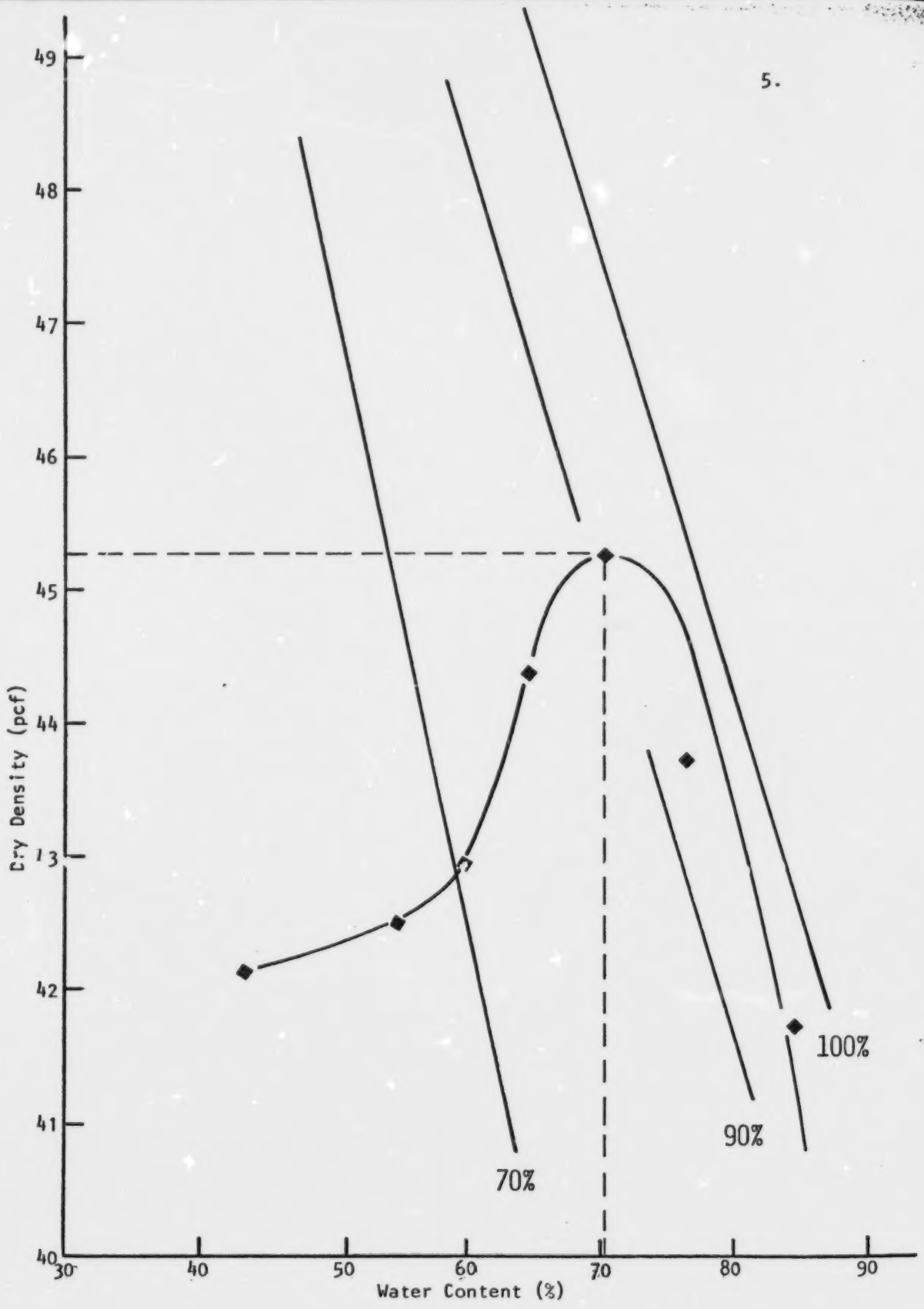

FIGURE NO. 1: STANDARD COMPACTION CURVE FOR FINE COAL.

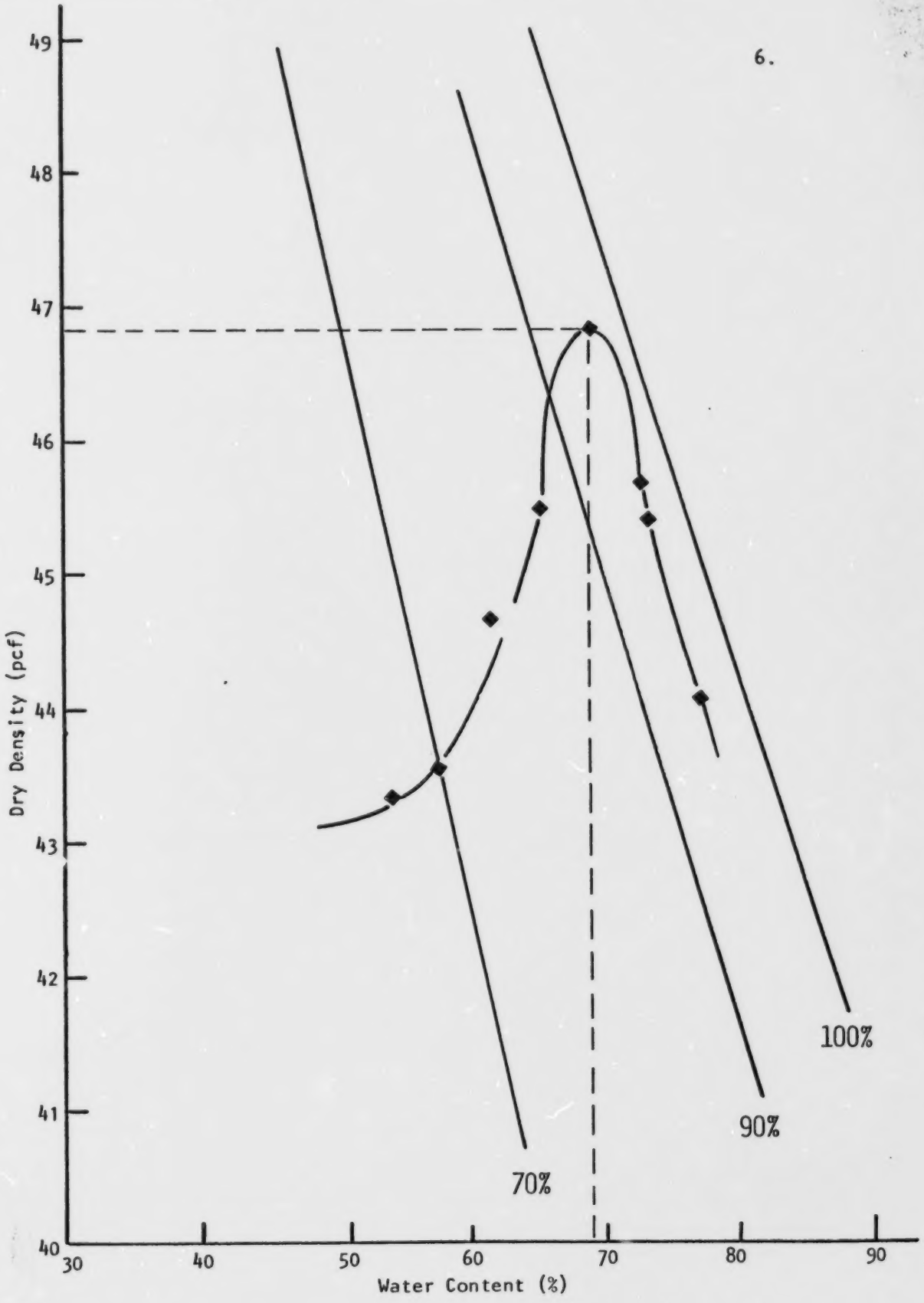

FIGURE NO. 2: STANDARD COMPACTION CURVE FOR COARSE COAL.

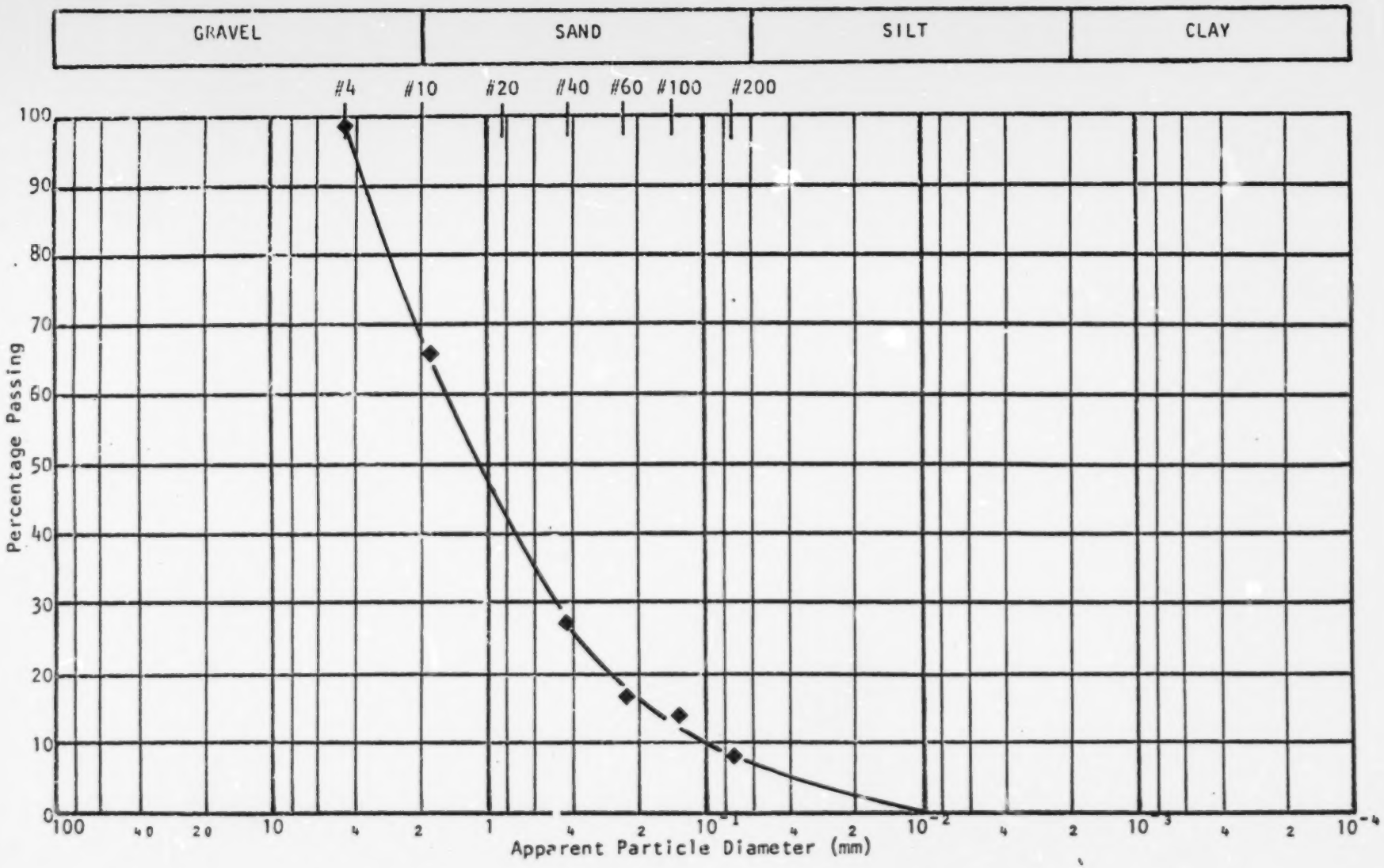

FIGURE NO. 3: PARTICLE SIZE DISTRIBUTION CURVE FOR FINE COAL — NO PREVIOUS COMPACTION STRESS.

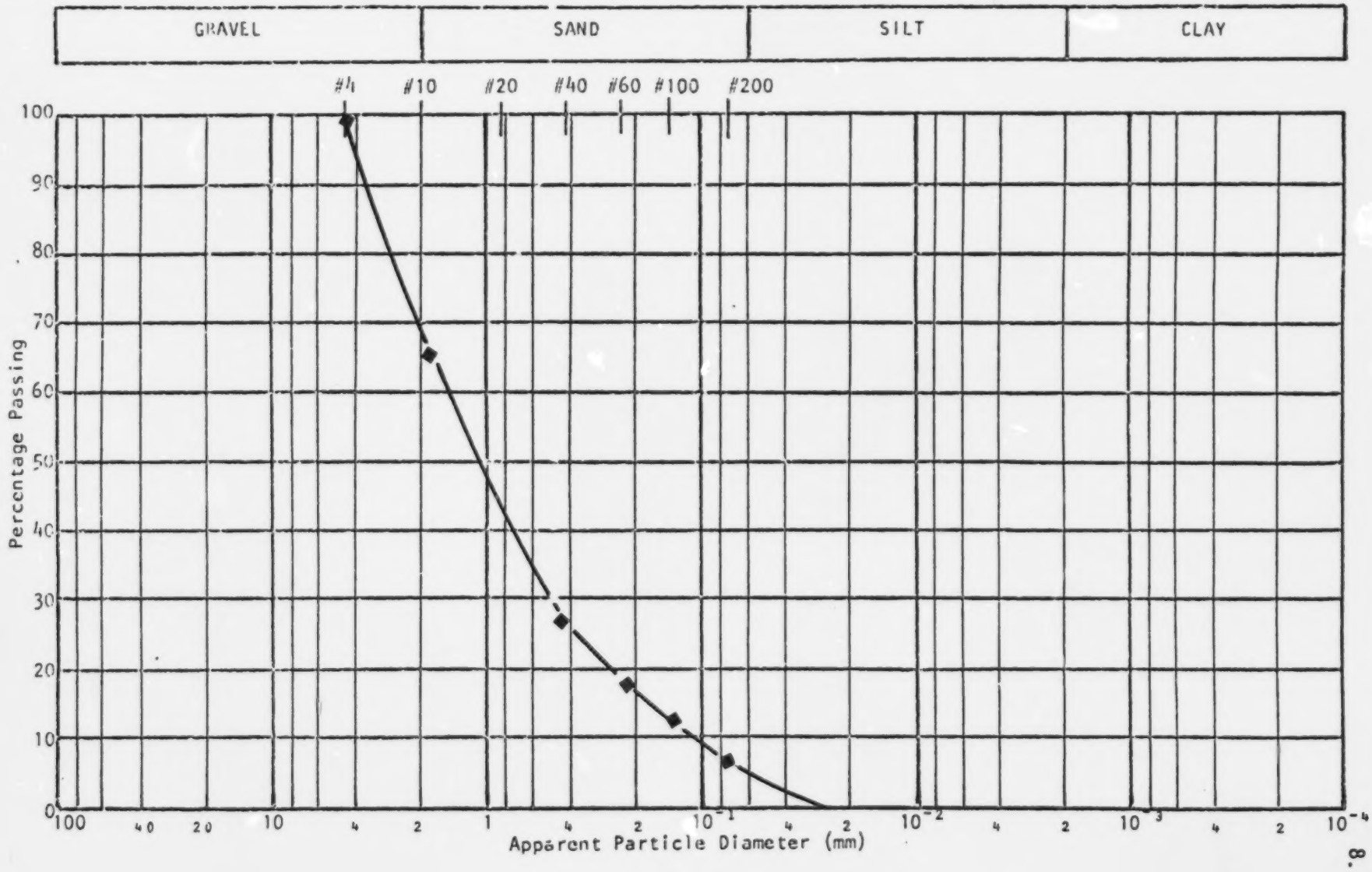

FIGURE NO. 4: PARTICLE SIZE DISTRIBUTION CURVE FOR FINE COAL — PREVIOUSLY COMPACTED UP TO 2000 PSI WITH MOISTURE CONTENT ~15%.

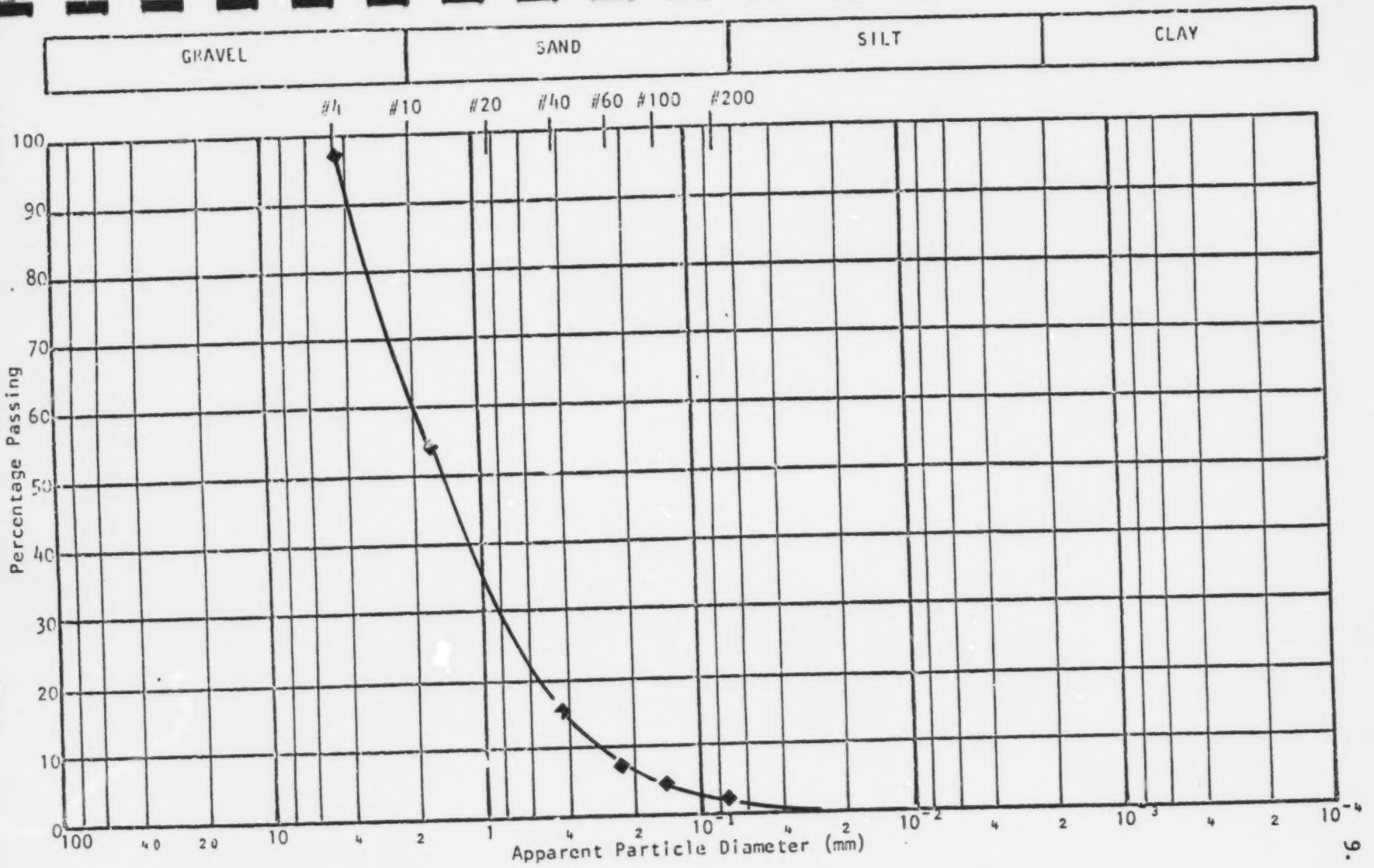

FIGURE NO. 5: PARTICLE SIZE DISTRIBUTION CURVE FOR FINE COAL — PREVIOUSLY COMPACTED UP TO 2000 PSI WITH MOISTURE CONTENT = +10%.

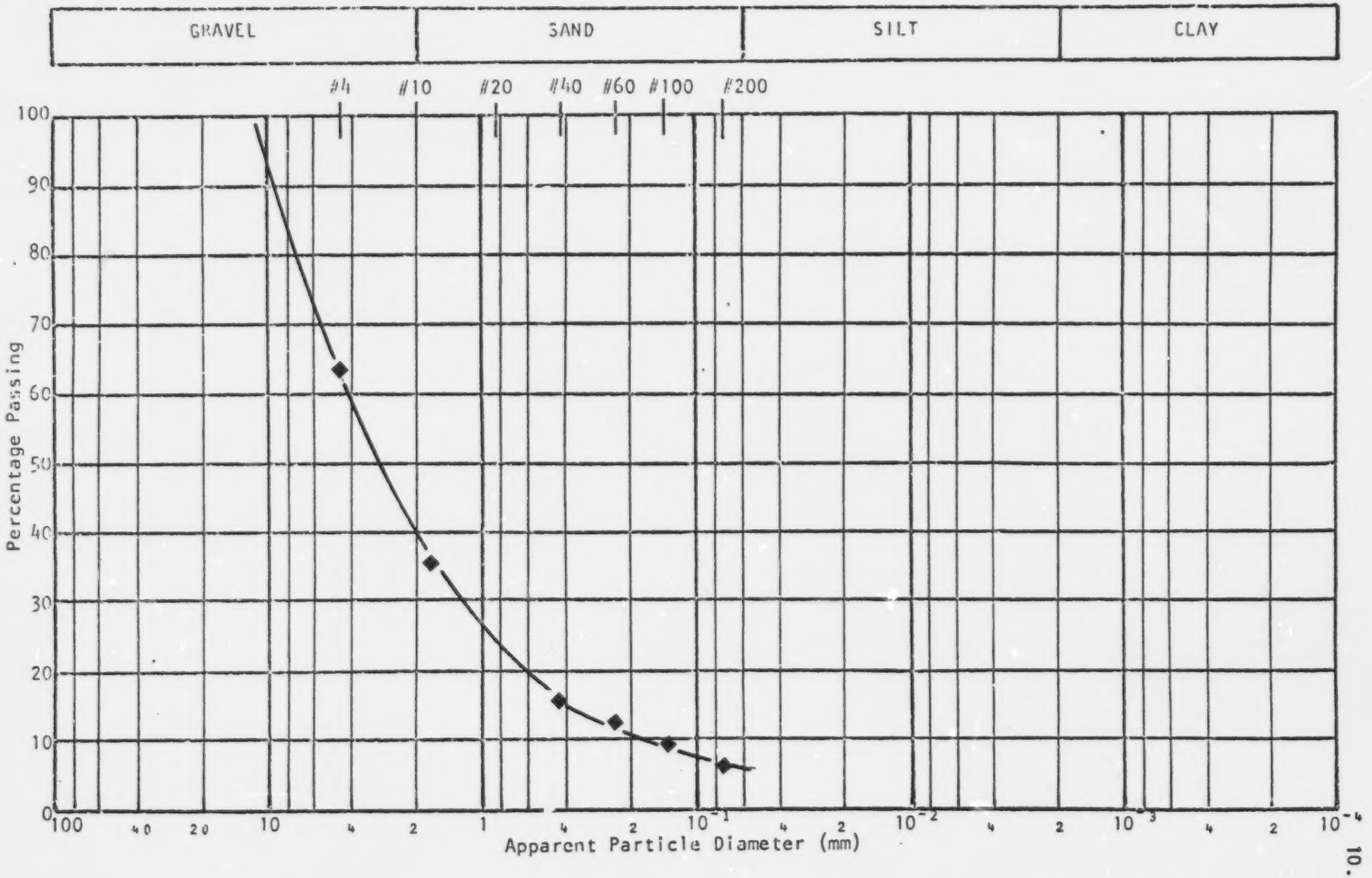

FIGURE NO. 6: PARTICLE SIZE DISTRIBUTION CURVE FOR COARSE COAL — NO PREVIOUS COMPACTION STRESS.

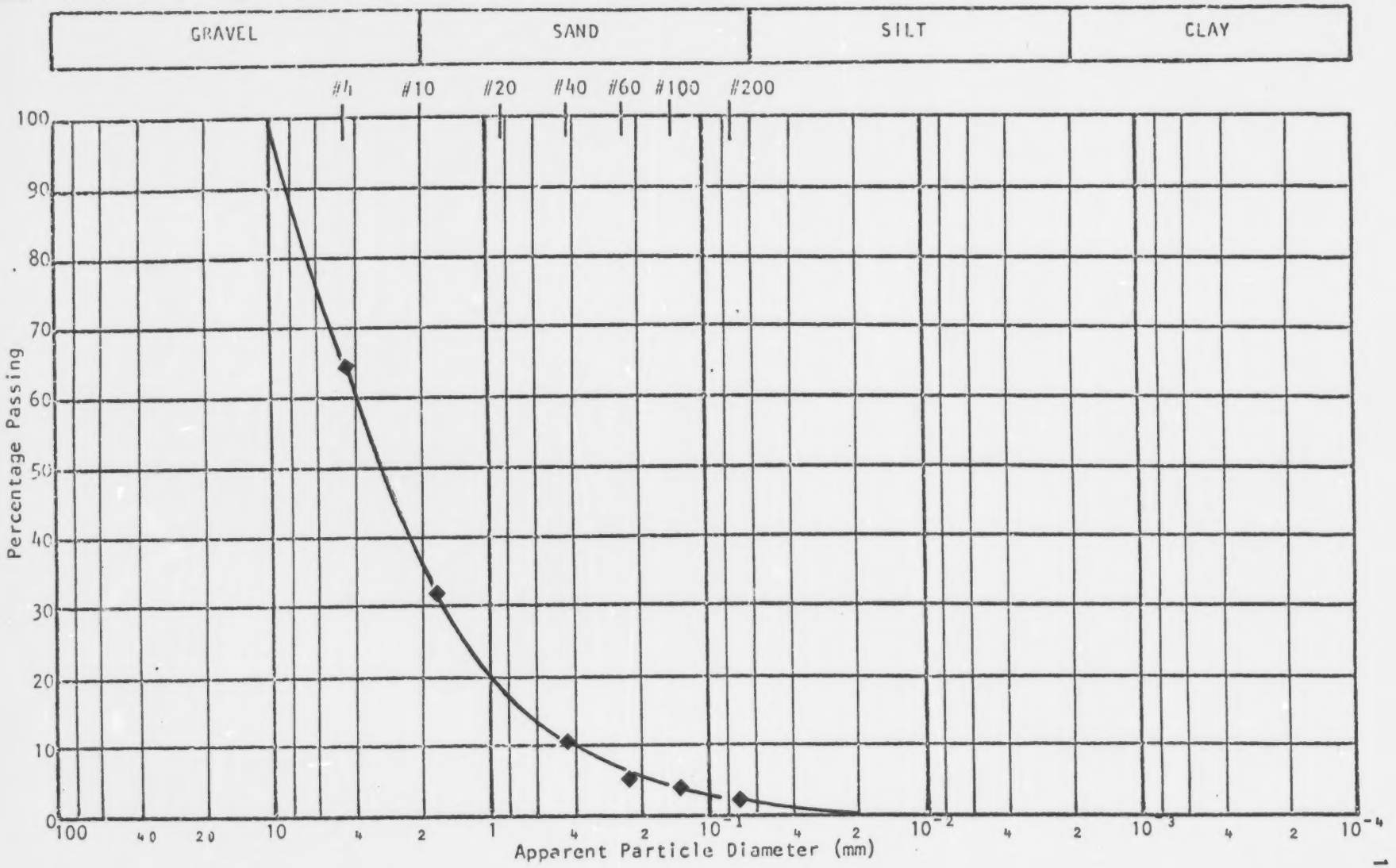

FIGURE NO. 7: PARTICLE SIZE DISTRIBUTION CURVE FOR COARSE COAL — PREVIOUSLY COMPACTED UP TO 2000 PSI WITH MOISTURE CONTENT ~15%.

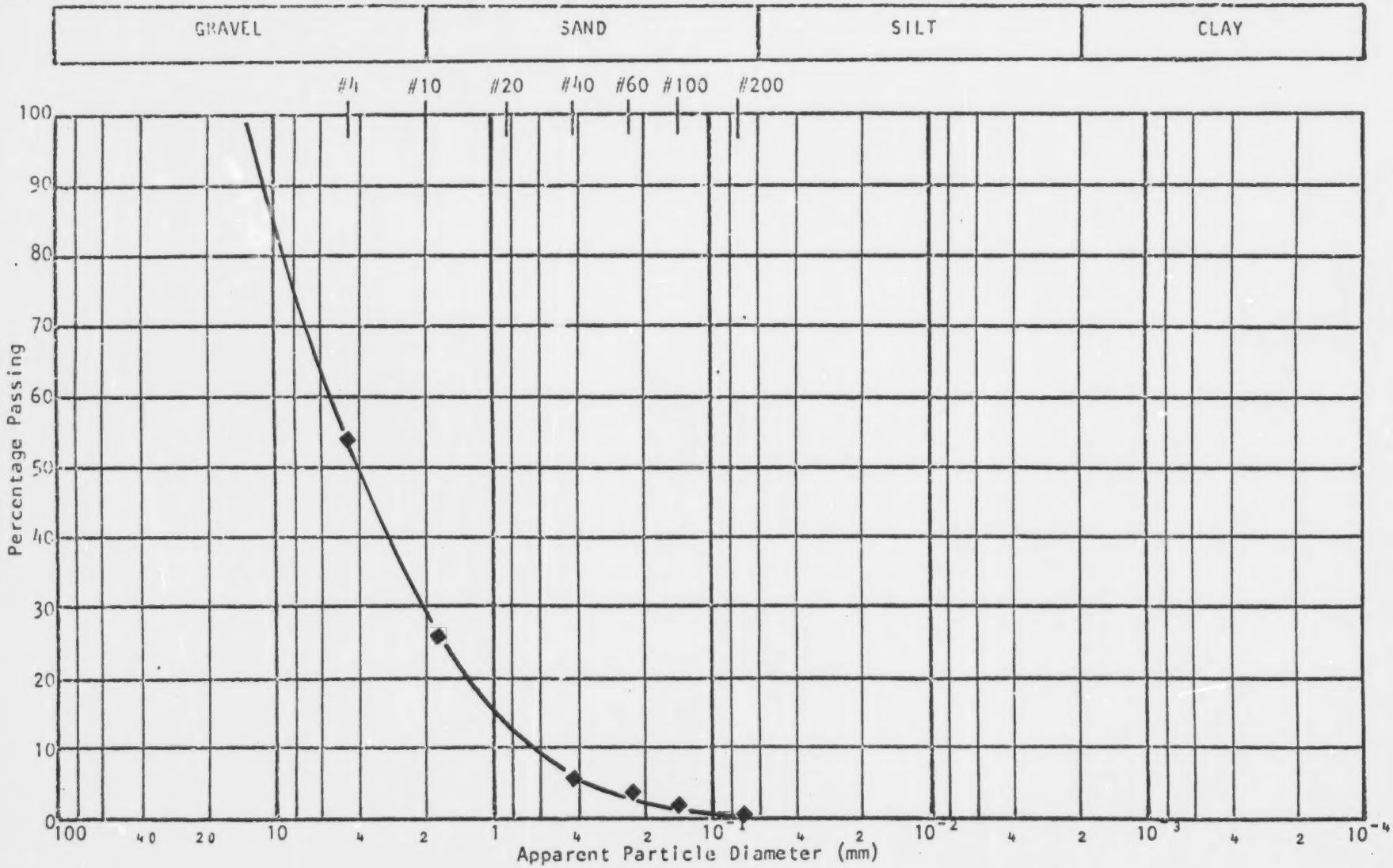

FIGURE NO. 8: PARTICLE SIZE DISTRIBUTION CURVE FOR COARSE COAL — PREVIOUSLY COMPACTED UP TO 2000 PSI WITH MOISTURE CONTENT = +10%.

of the fine coal has a particle size between 0.07 and 5 mm. For the coarse coal 92% of the coal sizes lay between 0.07 and 20 mm.

A summary of the particle size distribution for both of the coals under the various conditions is given in Table 2.

TABLE 2: PARTICLE SIZE DISTRIBUTION SUMMARY

TYPE OF COAL	CONDITION	PARTICLE SIZE* DISTRIBUTION			
		Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Coarse	Unstressed (as is)	62	33	5	0
Coarse	2000 psi, +10%	71	29	0	0
Coarse	2000 psi, ~15%	63	36	1	0
Fine	Unstressed	32	60	8	0
Fine	2000 psi, +10%	40	59	1	0
Fine	2000 psi, ~15%	30	65	5	0

*Gravel, sand, silt and clay refer to size of particle as indicated by ASTM standards.

The additional curves (Figures 4, 5, 7 and 8) given for the condition of 15% at 2000 psi and +10% at 2000 psi were to see if compaction of the samples, during the air permeability program, resulted in any substantial particle breakdown and whether this particle degradation was a function of the initial water and type of coal.

A quick perusal of Figures 3 to 8 does not seem to indicate any changes in the overall particle distribution during application of the compaction stress. It does show nevertheless that there is a certain variation in the compaction of each sample.

2.3 Specific Gravity

In order to calculate the basic parameters such as degree of saturation, void ratio, etc. which describe the basic mechanical properties of the coal particulate, it is necessary to know the value of the specific gravity. Two types of specific gravity were measured, the apparent and absolute values. The 'apparent' was measured by taking a representative sample (~50 grams) and completely drying it at 105°C. After drying the sample was carefully weighed and transferred into a volumetric flask of known volume. The volumetric flask containing the coal sample was then filled, three-quarters full, with de-aired distilled water and left for 15 minutes. During this 15 minutes it is assumed the coal adsorbed a certain amount of water. After this the volumetric flask was made up to the mark with more distilled water and then weighed. The apparent specific gravity was calculated using the following relationship—

$$G_s = \frac{G_t \quad W_s}{W_s + W_2 - W_1}$$

where G_s = specific gravity

G_t = specific gravity at temperature of experiment

W_s = weight of dry coal

W_2 = weight of filled volumetric flask

W_1 = weight of volumetric flask containing coal + distilled water.

The values for the apparent specific gravity for the fine and coarse coal are 1.20 and 1.29 respectively.

For the absolute specific gravity another representative sample was taken and ground up so that it all passed through a #200 sieve. The coal was

then weighed, placed carefully into a volumetric flask, half filled with distilled water and connected to the vacuum system to completely de-air. After de-airing the volumetric flask was made up to the mark with de-aired distilled water and then weighed. The absolute specific gravity was then calculated using the same formula as described previously. The value obtained was 1.644. Using this value the various degree of saturation lines indicated on the compaction curves were calculated.

3.0 AIR PERMEABILITY OF COMPACTED COAL SAMPLES

3.1 Introduction

A total of 144 tests were attempted in order to investigate the effects of types of coal, water content level and compaction stress level on the air permeability of coal cakes or compacts. As will be seen, although 144 tests were attempted, data was not obtained from some because the compaction stress produced a state of complete saturation which determines the upper boundary for any air permeability apart from means of diffusion. In Table 3 are briefly given the types of coal used and the conditions investigated.

TABLE 3: TYPES OF COAL CONDITIONS

TYPES OF COAL	CONDITIONS		
	AS RECEIVED	+10% MOISTURE	+15% MOISTURE
Coarse	✓	✓	✓
Fine	✓	✓	✓

The initial moisture contents of the coarse and fine coals were first determined 'as received' and the calculated plus 10 and 15% moisture content was added to the coal.

In preparing the large number of samples to be tested, there was some difficulty in preparing the samples with the same moisture content. Therefore, it will be seen that in some cases the +10% or 15% level will show some variation in value.

3.2 Experimental Method

In Figures 9 and 10 are presented both a diagrammatic and detailed

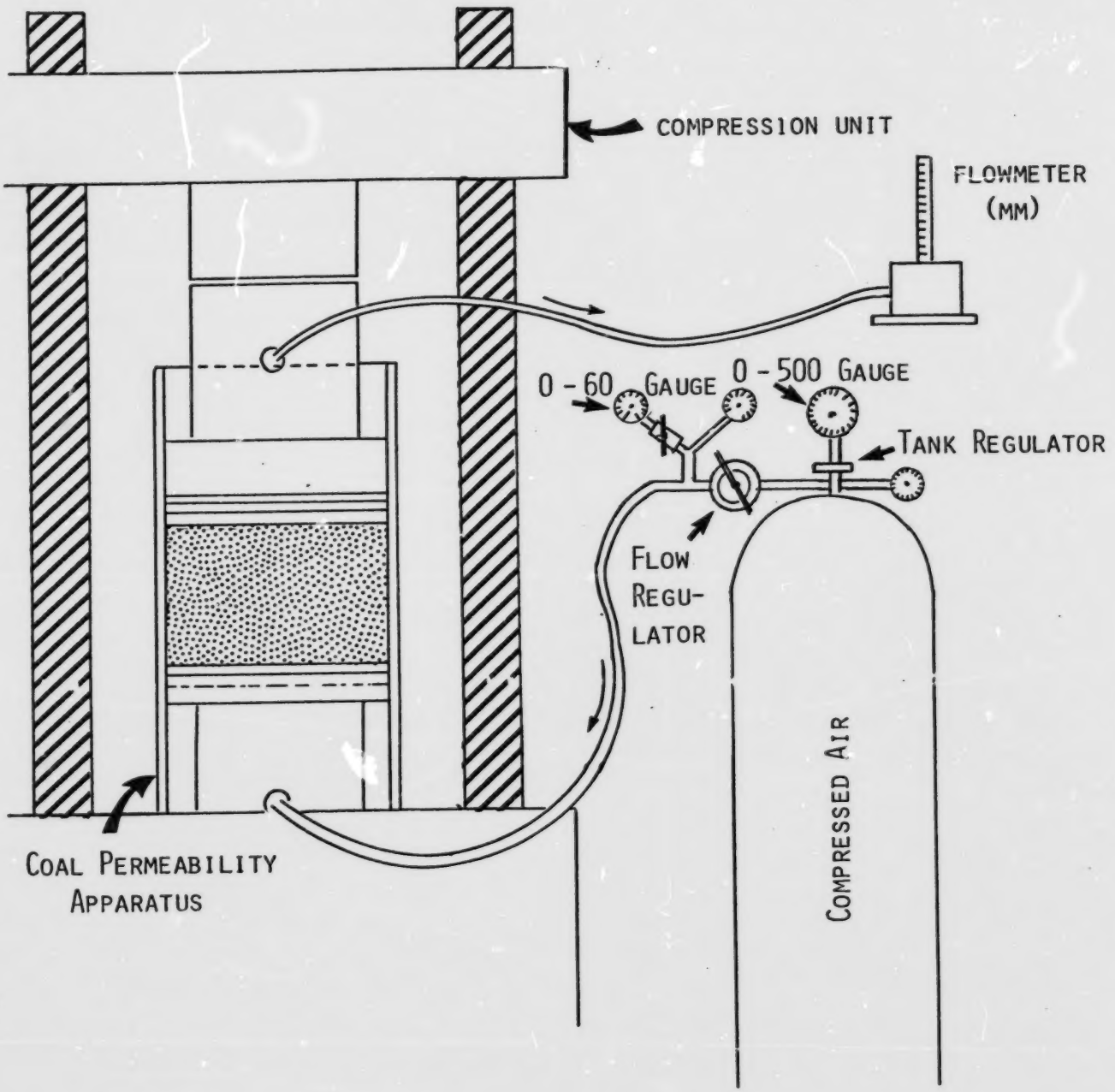

FIGURE NO. 9: SCHEMATIC REPRESENTATION OF OVERALL AIR COMPACTION SYSTEM.

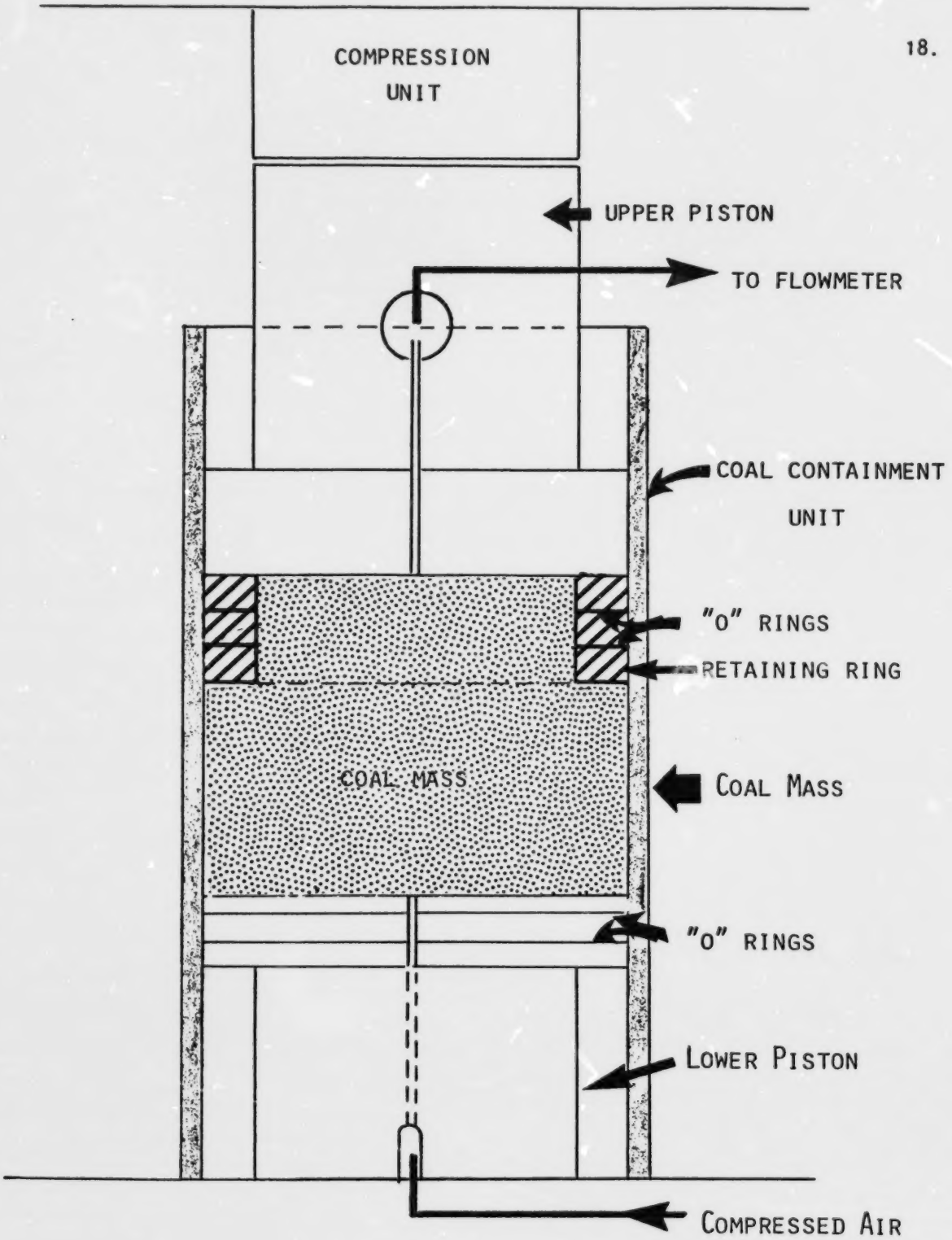

FIGURE NO. 10: SCHEMATIC REPRESENTATION OF COMPACTION CYLINDER.

description of the complete system used not only to apply the compaction stress, but also to measure the air permeability and blowout pressure.

Briefly there are three main components of the test system, i.e. the compressed air cylinder and regulator; the compaction set-up and the flow measuring system. The compaction mould or cylinder is composed of four parts, the sample cylinder, the top and bottom pistons, the retaining ring and the blow out helmet. The top and bottom pistons, as well as the blow out helmet are fitted with quad rings to ensure smooth movement during compaction whilst maintaining an air-tight seal during the permeability stage.

To commence the test, the bottom piston was pushed into the sample cylinder and then set-up vertically. Into the cylinder was then poured the coal; the type and moisture content being previously adjusted. In pouring in of the coal it is difficult to be able to produce a completely homogeneous cake, and it is certain that in this process there would be some separation of the larger and smaller particles.

After pouring in the sample, the side of the cylinder was lightly tapped to initially pack down the coal prior to compaction. Two different sample cylinder heights were used in order to obtain final sample heights of approximately 5"and 10". These two different height conditions are referred to as "small" and "large" samples. After initially packing down the sample the retaining ring was seated on top of the coal, followed by the top piston. The apparatus was then carefully centered in the Rhiele Loading Press, and the required compaction stress was applied through contact with the top piston. The maximum capacity of the Rhiele is 60,000 lbs. After the required load was applied the height of the compacted sample was measured. Whilst maintaining the stress level the 'air permeability' set-up was attached.

The bottom of the sample was connected to the compressed air cylinder via a pressure regulator and the top of the sample to the Fisher flow meter. In measuring the air permeability, the required pressure was applied to the base of the sample and the resultant flow was monitored by the flow meter. At each compaction stress level the flow rate was measured at several applied air pressure levels. The only restriction applied was that the supplied air pressure should not exceed the compaction stress level. Also, the air flow rate could not be measured if the rate was in excess of 40 litres per minute.

Two different types of compaction-air permeability test procedures were followed and are referred to as "incremental" and "single" level tests. In the single level test a completely new sample was used for each compaction-air permeability test whereas with the incremental tests the same sample was compacted under several increasing compaction stress levels and at each level the air permeability was measured. Before and after completion of the air permeability, the sample height was measured and after completion of the test the water content was measured.

For several of the tests a blow out test was attempted. For this test the sample was first compacted following the measurement of the air permeability. The sample was then unloaded and the top piston removed and replaced by the hollow blow out helmet. (Volume of helmet = 154.4 in^3.) After this the pressure was reapplied to the sample. The air pressure was then applied to the base of the sample and increased until the inflow and outflow pressure was similar or the sample was physically dislodged from the sample cylinder. This pressure was taken as the blow out pressure.

3.3 Presentation of Data

In Appendix Tables A-2 to A-39 are presented the raw data obtained from the compaction—air permeability test in terms of the compaction stress level and the flow rates at the various applied air pressure levels. Also shown in Appendix Figures A-1 to A-27 are the plots of air pressure versus flow rate for the same tests. Out of a total of 144 tests attempted, there were found to be twenty-nine conditions under which the air permeability was found to be zero. Of course the data and curves for these tests will not be found in the previously discussed Appendix Tables and Figures. A list of the conditions under which the air permeability was found to be zero is shown in Table 4. As can be seen from Table 4, the condition of zero permeability was found for the wetter samples and at the higher stress levels.

In the forthcoming section the data is discussed in detail with some comments about variability of samples, a personal view of the concepts and factors which affect the air permeability values and an analysis of the data

With respect to the analysis of the data it should be pointed out that the analysis is a personal interpretation of the data by the present author, Dr. David Taplin, and not that of G.R.C. and the time spent on the analysis and its presentation is given without any personal charge and is given as an aid to the client in his decision-making role.

TABLE 4: SUMMARY OF CONDITION FOR ZERO AIR PERMEABILITY

TEST CONDITION	TEST NO.	MOISTURE CONTENT (%)	COMPACTION STRESS LEVEL (psi)					
			50	100	200	500	1000	2000
large/fine/ incremental/	17, 18	38.9					✓	✓
small/fine/ incremental/	70, 71, 72	44.3				✓	✓	✓
small/ coarse/ incremental	84	36.8						✓
	88, 89, 90	42.4				✓	✓	✓
	101	35.3						✓
	106, 107, 108	41.3				✓	✓	✓
large/coarse/ single	114	36.1						✓
large/fine/ single	125	44.2					✓	
	126	42.9						✓
small/coarse/ single	131	35.8					✓	
	132	36 6						✓
small/coarse/ single	134	41.0					✓	
	135	40.3						✓
small/fine/ single	142	41.0		✓				
	143	40.1					✓	
	144	39.9						✓
large/coarse/ incremental	36	41.7						✓
small/fine/ incremental	52, 53, 54	41.1				✓	✓	✓
large/ coarse/ single	115	44.3		✓				
	116	44.1					✓	
	117	42.9						✓

✓ = condition of zero permeability

3.4 Variability of Samples

Before commencing to discuss the actual data results or embarking on any formal analyses it is necessary to make a few comments about the sample variability. It is well known amongst soil mechanics experts that there is a tremendous problem in obtaining reproducible behaviour with granular materials. This problem is further accentuated when one is dealing with particle size degradeable material such as coal.

Even though one has carefully tried to obtain equally good representative samples there is no guarantee that the internal fabric of the sample has any similarity. It is already obvious from the particle size distribution curves shown in Figures 3 to 8 that the samples do have some variability in particle size composition, especially in terms of the fine particles. Also in compaction of the sample there is a tendency that the material closest to the piston face will be highly compacted; more so than the material in the centre. This will lead to non-uniform gradient across the sample. Also, a highly compressed zone close to the piston may control the air permeability of the sample in general. It should be pointed out that the material properties such as dry density and permeability are calculated assumming a uniformly packed sample and thus the data have to be treated with some caution.

The obvious limits in variability from one test to another is in the dry density — compaction stress relationships. In Appendix Figures B-1 to B-10 are given the dry density, γ_d (pcf) versus the log of the compaction stress cuves for all of the tests undertaken and in Tables 5 and 6 is presented a summary of this data.

TABLE 5: SUMMARY OF DRY DENSITY FOR FINE COAL MATERIAL

TYPE OF SAMPLE	RANGE OF W/C (%)	DRY DENSITY (pcf) AT VARIOUS COMPACTION STRESSES			
		0 psi	100 psi	1000 psi	2000 psi
S, I, 1	19.0	44.0	47.3	57.4	61.2
S, I, 2	19.6	38.0	43.0	51.0	54.1
L, I, 1	19.0	40.2	46.6	57.5	62.0
S, 0, 1	18.8 - 13.6	—	—	—	—
L, 0, 1	~16.0	36.0	39.1	53.6	
S, I, 1	45.8	36.1	41.0	51.7	56.6
S, I, 2	2.0	31.4	36.1	44.1	47.4
L, I, 1	42.9	36.6	39.3	48.0	51.6
S, 0, 1	40.4	33.8	38.2	45.6	48.6
L, 0, 1	40.4	34.8	39.9	50.0	53.8
S, I, 1	69.8	26.3	35.6	N/A*	N/A
S, I, 2	79.5	22.9	31.4	N/A	N/A
L, I, 1	63.7	29.4	37.0	48.0	N/A
S, 0, 1	69.5 - 66.3	30.9	(36.3)*	(46.0)	(53.5)
L, 0, 1	75.1 - 79.8	34.8	34.3	(39.5)	(44.7)

S = small sample approximately 5" in height

L = large sample approximately 10" in height

I = incremental

0 = single (in second column under type of sample)

1 or 2 = series 1 or 2

N/A*, ( )* or ( ) = value of dry density is estimated or not available because of water being expelled.

TABLE 6: SUMMARY OF DRY DENSITY FOR COARSE COAL MATERIAL

TYPE OF SAMPLE	RANGE OF W/C (%)	DRY DENSITY (pcf) AT VARIOUS COMPACTION STRESSES			
		0 psi	100 psi	1000 psi	2000 psi
S, I, 1	23.9	40.4	47.2	56.6	61.4
S, I, 2	14.2	38.0	43.9	52.0	N/A*
L, I, 1	13.0	44.2	51.7	56.3	59.3
S, 0, 1	14.4 - 15.5	(41.8)* 39.9 - 43.6	45.0	53.7	59.9
L, 0, 1	15.7 - 16.9	40.8) 40.1 - 41.5	44.9	54.4	59.4
S, I, 1	58.2	29.3	39.5	47.0	(50.0)
S, I, 2	54.6	30.1	39.2	46.3	(48.3)
L, I, 1	50.8	34.1	37.3	44.1	46.6
S, 0, 1	54.8 - 57.7	(35.8 - 38.1)	48.7	(57.6)	(60.4)
L, 0, 1	52.7 - 56.7	31.4 29.2 - 33.6	32.2	48.0	(45.9)
S, I, 1	73.6	31.9	40.5	N/A	N/A
S. I, 2	70.4	28.3	37.0	N/A	N/A
L, I, 1	71.5	28.4	36.9	(44.2)	(46.2)
S, 0, 1	67.5 - 72.7	(33.7)	40.9	(48.4)	(55.5)
L, 0, 1	85.5 - 70.9	31.0 29.5 - 32.4	(38.8)	(40.8)	(40.6)

S = small sample approximately 5" in height

L = large sample approximately 10" in height

I = incremental

0 = single (in second column under type of sample)

1 or 2 = series 1 or 2

N/A*, ( )* or ( ) = value of dry density is estimated or not available because of water being expelled.

The values of the dry density given both in Appendix Figures B-1 to B-10 and Tables 5 and 6 are average values. As discussed in the earlier section dealing with the experimental method, the length of the sample was measured before and after the air permeability test because of the difficulty of maintaining a constant stress using the Rhiele machine. The difference in height usually accounted for a maximum of ± 2 pcf error in the values of the dry density. Also the number of asterisks shown in Tables 5 and 6 refer to estimated values of the average dry density at which no air permeability was measured.

A perusal of Tables 5 and 6 shows that in the original material there could be up to 12 pcf difference in the initial dry density, although in general the variation in the average is in the order of ± 10%.

Inspection of Appendix Figures B-1 to B-10, which show the changes in dry density with level of compaction stress for all of the tests, it can be seen that the variability in each sample is clearly seen in the continuity of these curves. The incremental tests are more consistent than the individual single tests. In the next section will be discussed the basic concepts behind an analysis of the test data.

3.5 Analysis of Coal Permeability

3.5.1 Introduction - Concepts

As can be seen from Table A-2 to A-39 which represent the basic data, there is a variety of heights, moisture contents, weights and types of coals investigated during this experimental program.

From an inspection of the behaviour between flow and pressure, very little information can be obtained. The air permeability as will be discussed more fully is dependent upon numerous factors. Examination of the air pressure— flow rate curves shown in Figure A-1 to A-27 clearly show the following trends:

(1) for a specific condition of compaction stress, coal type and initial moisture content level, an increase in applied air pressure results in an increase in flow rate,

(2) also for the same condition as in (1) an increase in compaction stress normally results in a decrease in flow rate under the same applied air pressure, and

(3) also for the same conditions as in (1) the higher water content at the same density, the lower the permeability and the finer the coal, the lower the permeability.

These three trends are firstly only qualitative and secondly, obvious from basic material considerations. In fact these statements are only saying if one reduces the available pore size, then the permeability is subsequently reduced. This decrease in pore size availability can be seen in either increase in saturation or increase in density, or both.

In order to more fully understand and try to explain the factors controlling the flow of air through the compacts, one must look at the effects of several factors which control the permeability. These factors include dry density, degree of saturation, volume of air voids, void ratio and the parameter $\frac{e^3}{e+1}$. It is doubtful if the air permeability is dependent upon only one of these parameters and that there is a unique relationship.

According to Matyas (1966) who performed a limited number of air permeability tests on compacted clays, the air permeability can be calculated using Darcy's Law, i.e.

$$Q = kiA \quad \text{or} \quad = k \frac{P}{L} A$$

where Q = flow rate (cm^3/s)

k = permeability (cm/s)

i = pressure gradient $= \frac{P}{L} = \frac{\text{pressure (cm } H_2O)}{\text{length of sample (cm)}}$

and A = area of sample (cm^2).

If Darcy's Law applied, then there should be a linear relationship between the air pressure level and the resulting flow rate. In general this was found although the flow rate did seem to bounce around in some cases and also in others there appeared to be linearity, but over specific ranges. The change in the linear behaviour could be due to several reasons:—

(1) flow characteristics,
(2) pore size distribution,
(3) particle migration,
(4) viscosity effects due to interaction of the flowing air and the pore fluid,
and (5) applied pressure being high enough to displace water from voids, hence opening up more void space.

This increase in permeability is seen as a decrease in the slope of the applied air pressure versus flow rate curve. In the forthcoming section the manner in which the parameters, such as density, void ratio, degree of saturation, etc. affect the permeability will be discussed.

3.5.2 Inspection of Unique Relationship

In the previous section was discussed the basic concepts concerning "permeability" and the factors which should influence its value. Having listed such parameters as dry density, degree of saturation, void ratio, volume of air void: volume of solids ratio, and $e^3/(1+e)$ as being likely parameters to relate with permeability one must then ask the question: Is there a unique relationship between permeability (air) and any of these parameters, such that the permeability of any coal in any condition (i.e. level of water content or particle size distribution) can be reasonably estimated?

In the previous section it was stated that if Darcy's Law applies there should be a linear relationship between the flow rate and applied pressure. As can be seen from Appendix Figures A-1 to A-27 this is true in most cases. A linear regression was carried out on the applied pressure versus flow rate curves and the slope inserted into the following equation in order to calculate the permeability constant k

$$k = \frac{1}{m} \cdot L \times K$$

where m = slope of pressure versus flow rate

L = height of sample

K = conversion factors to make sure 'k' is in units of cm/s.

In Figures 11 to 24 are presented the plots of dry density, degress of saturation, void ratio, V_{air}/V_{solids} and $e^3/(e+1)$ versus the air permeability value for a typical example of fine and coarse coal. Each of these graphs show the variation with different initial water contents. Also shown for each type of coal is the variation in permeability with level of compaction stress.

Inspection of Figures 11 to 24 for fine and coarse coal respectively, show that for a specific coal type and specific water content there are relationships between the various engineering parameters and permeability, but there is not a unique relationship. Nevertheless, it should be pointed out that although the present author has not established an unique relationship this is not to say that there does not exist some parameter. Because of this latter reason the basic data has been included in the report in Appendix Table C.

In the forthcoming section a practical solution will be discussed rather than a theoretical solution.

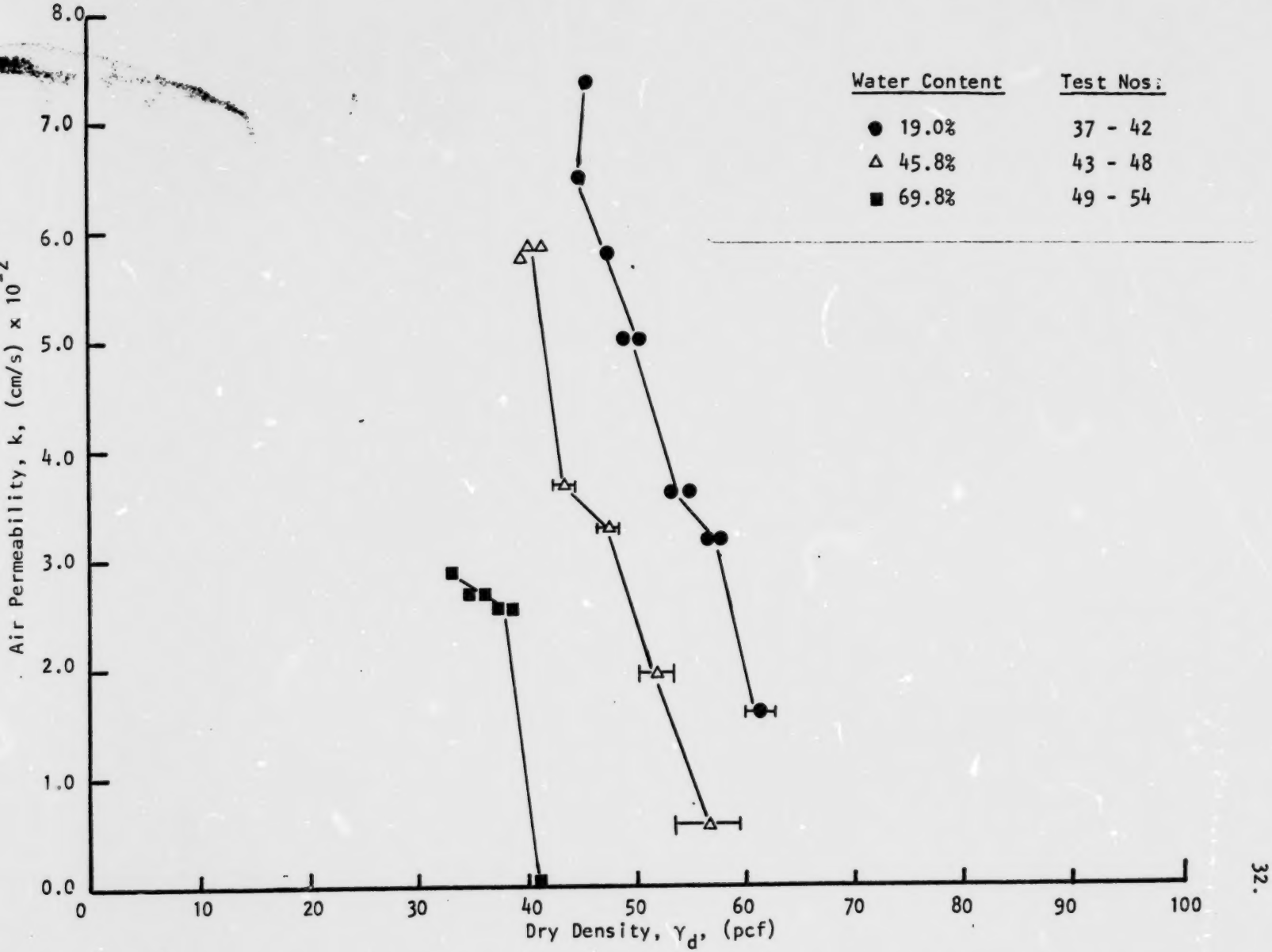

FIGURE NO. 11: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF DRY DENSITY FOR SMALL, FINE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

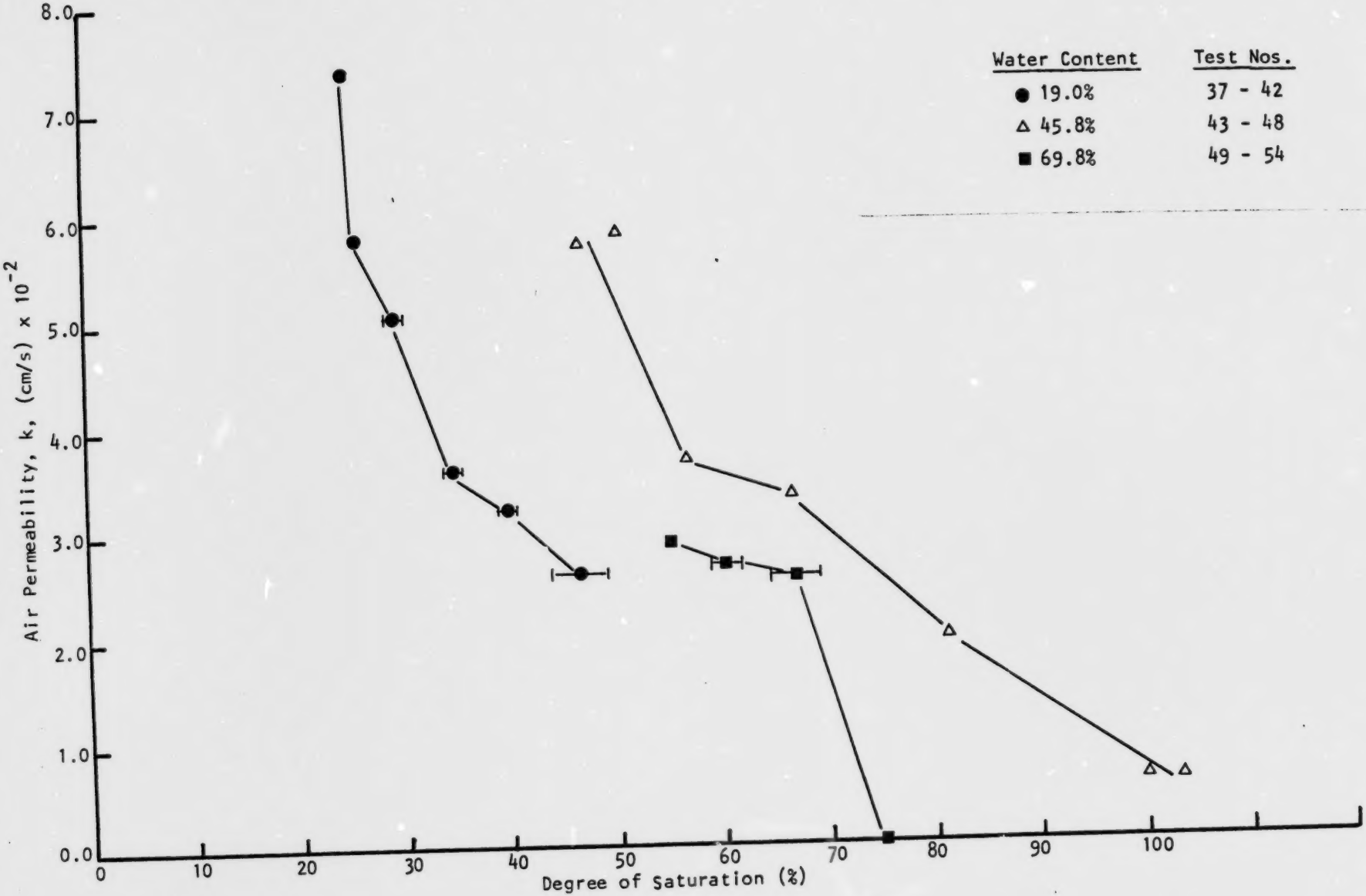

FIGURE NO. 12: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF DEGREE OF SATURATION FOR SMALL, FINE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

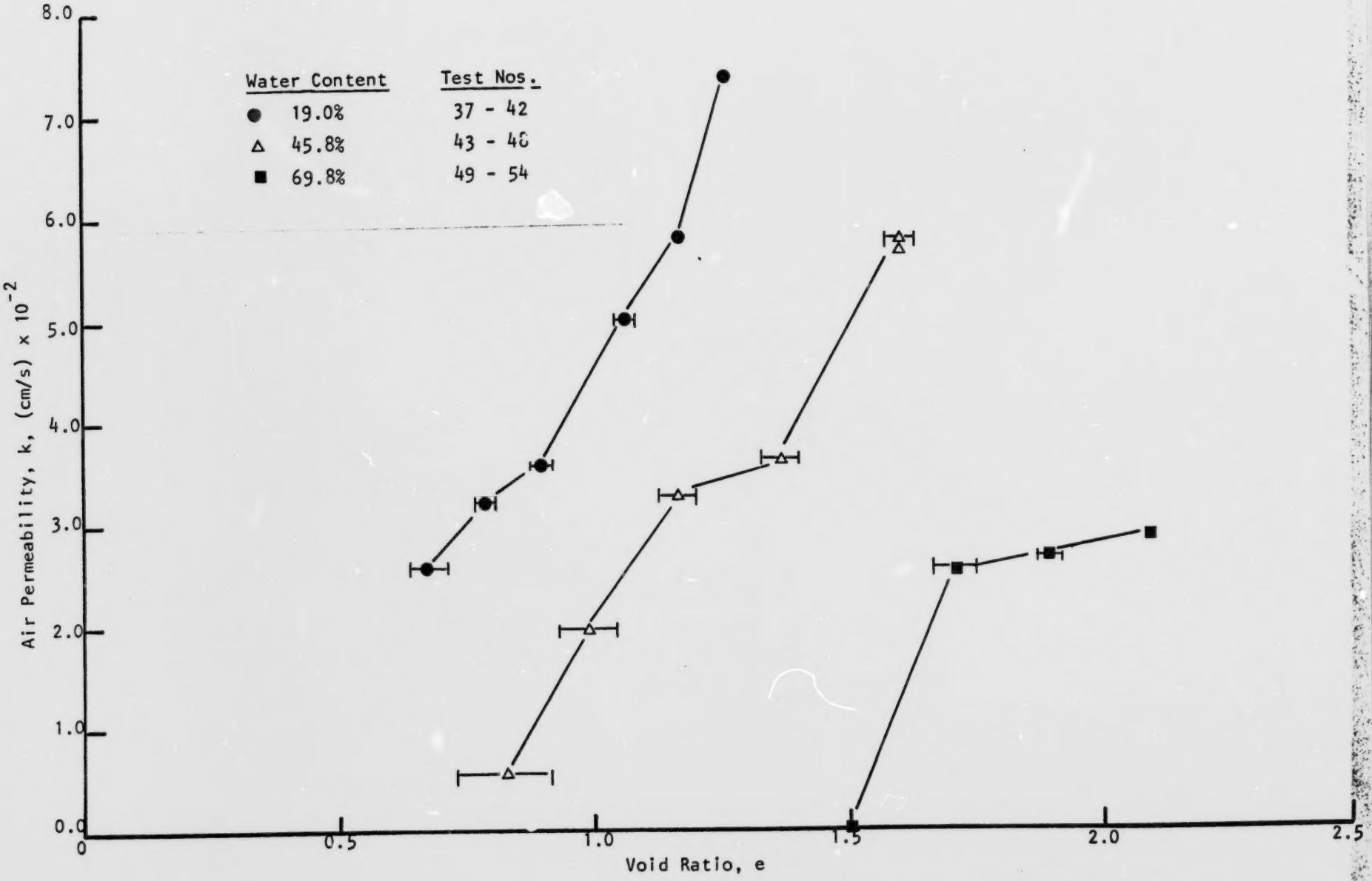

FIGURE NO. 13: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF VOID RATIO FOR SMALL, FINE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

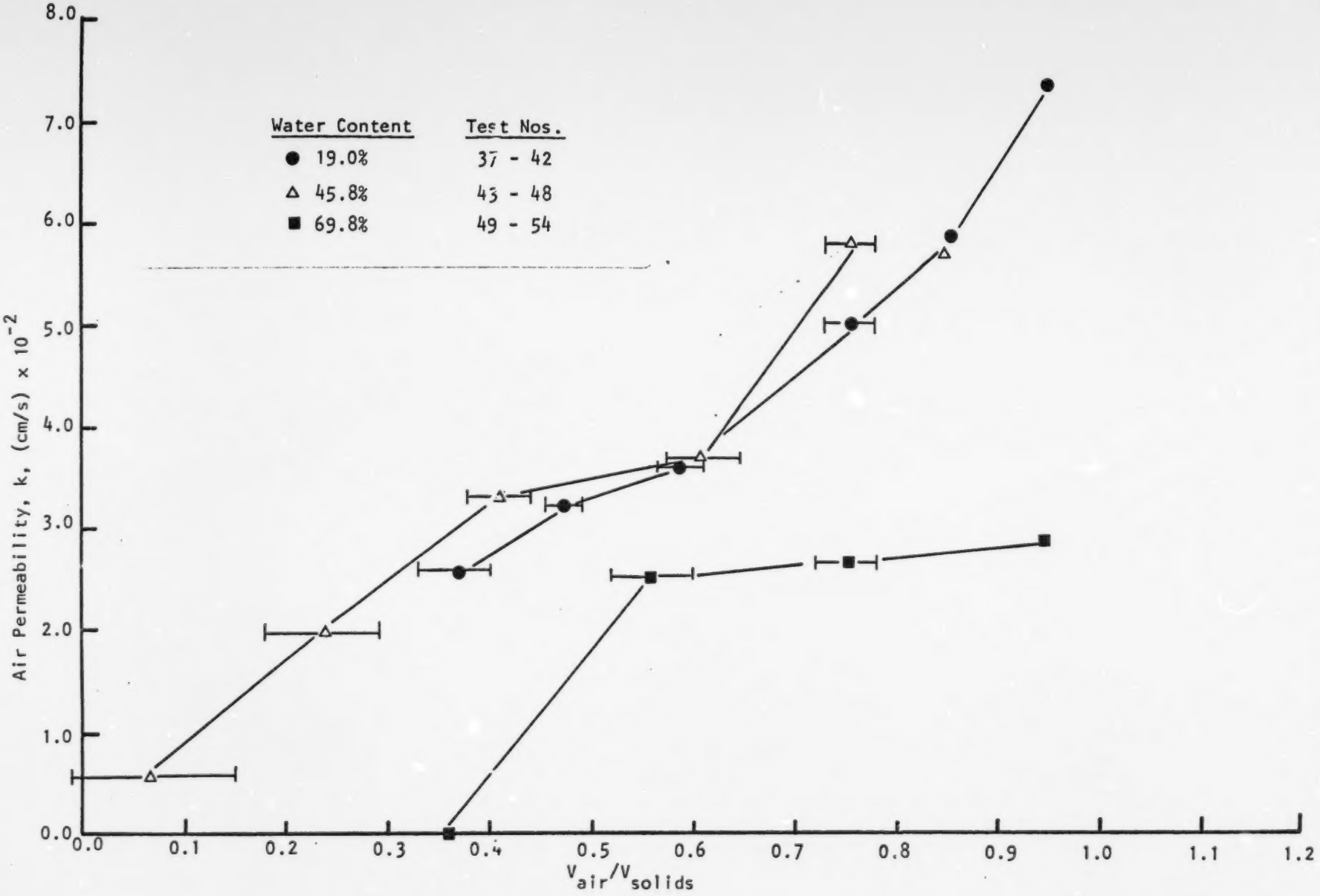

FIGURE NO. 14: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF V_{air}/V_{solids} FOR SMALL, FINE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

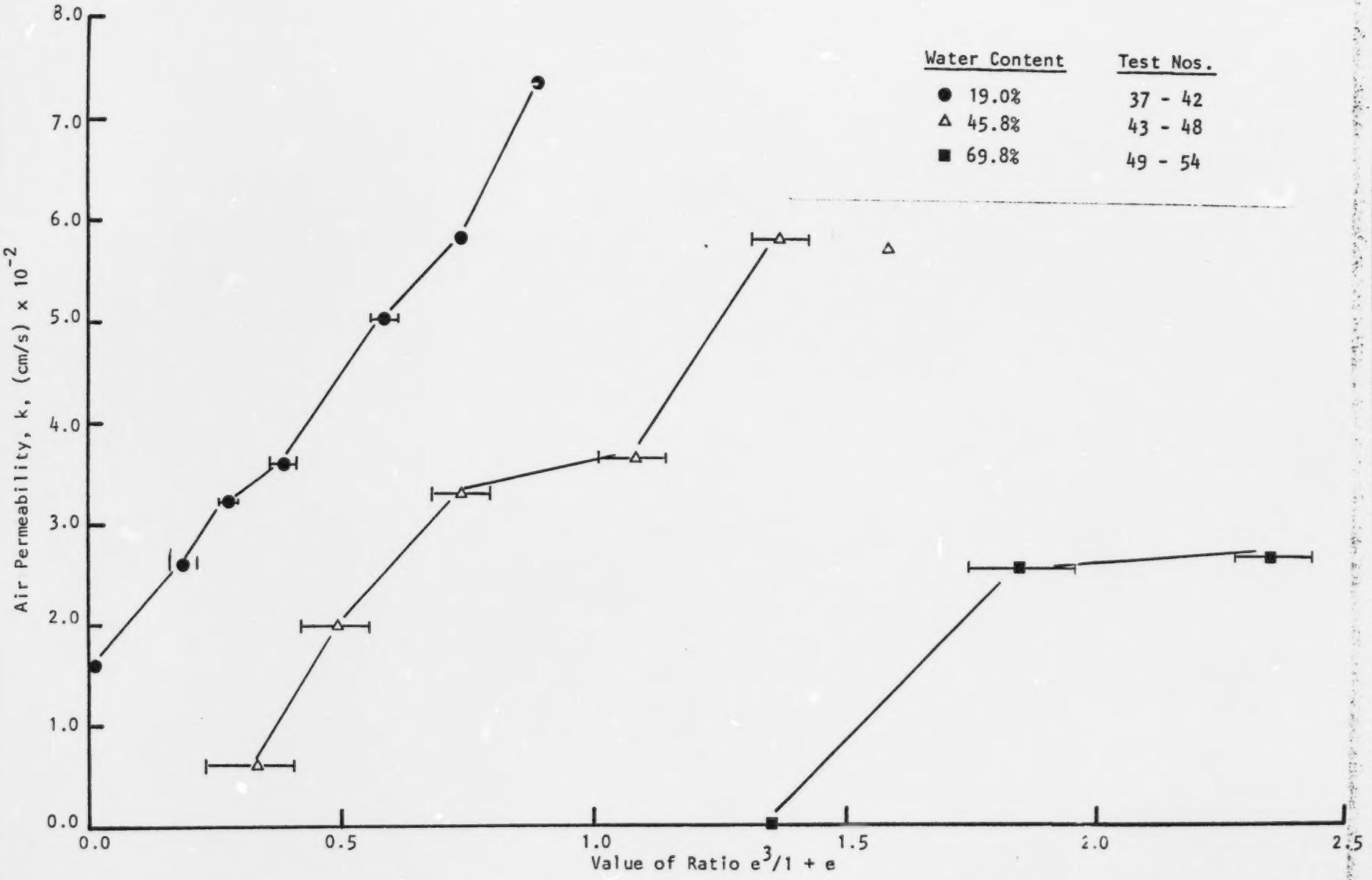

FIGURE NO. 15: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF $e^3/1 + e$ FOR SMALL, FINE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

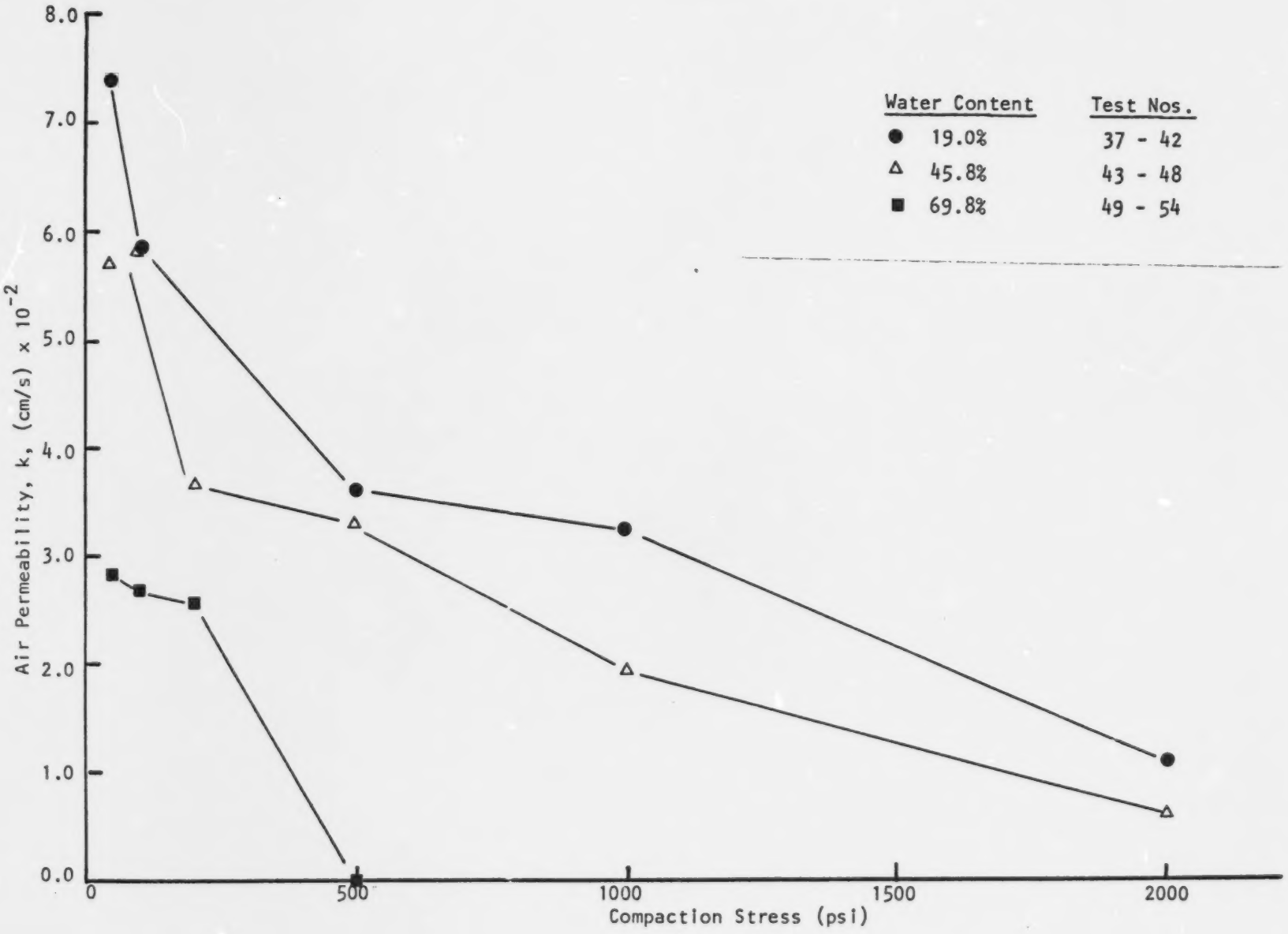

FIGURE NO. 16: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF COMPACTION STRESS LEVEL FOR SMALL, FINE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

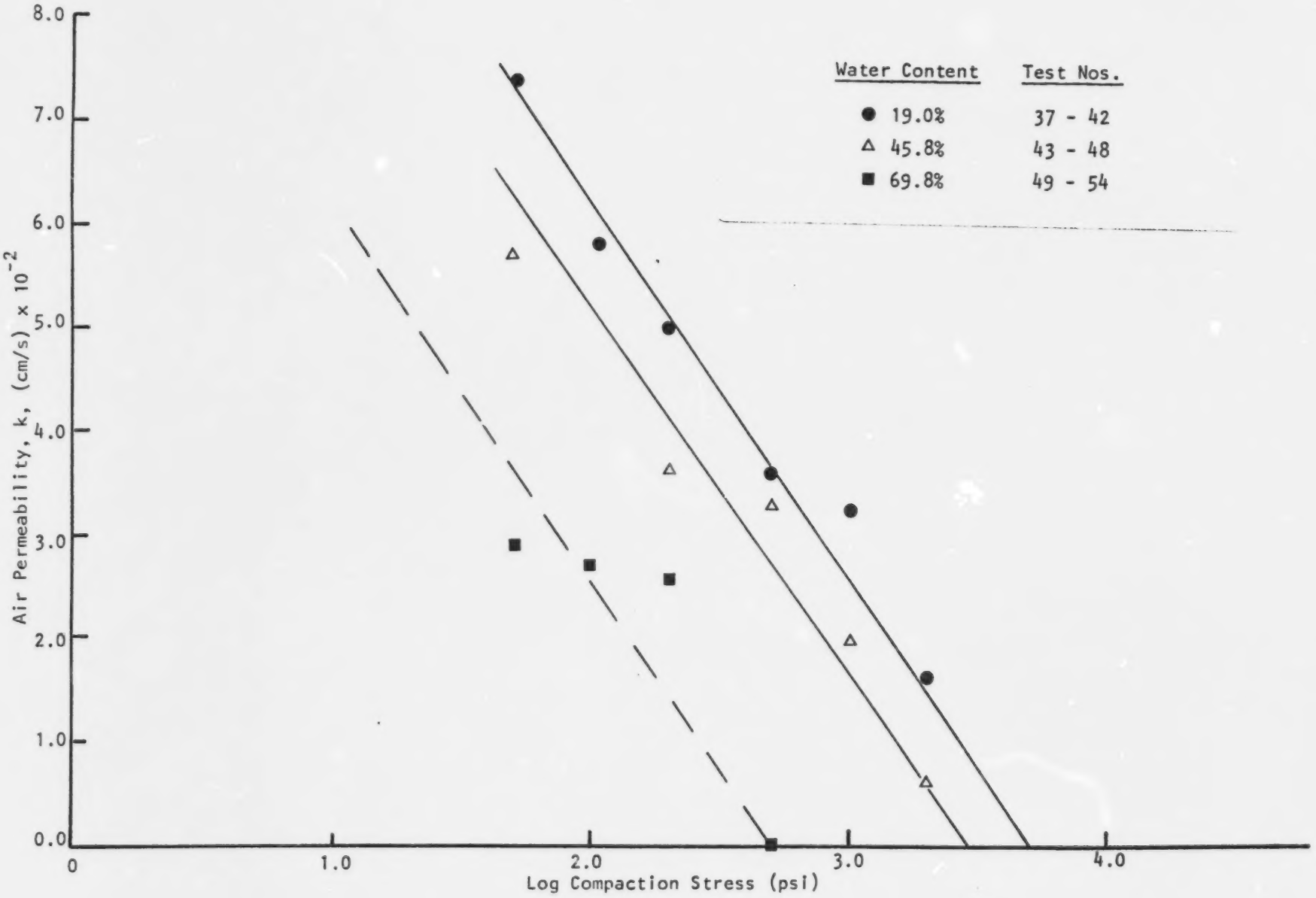

FIGURE NO. 17: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF LOG COMPACTION STRESS LEVEL FOR SMALL, FINE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

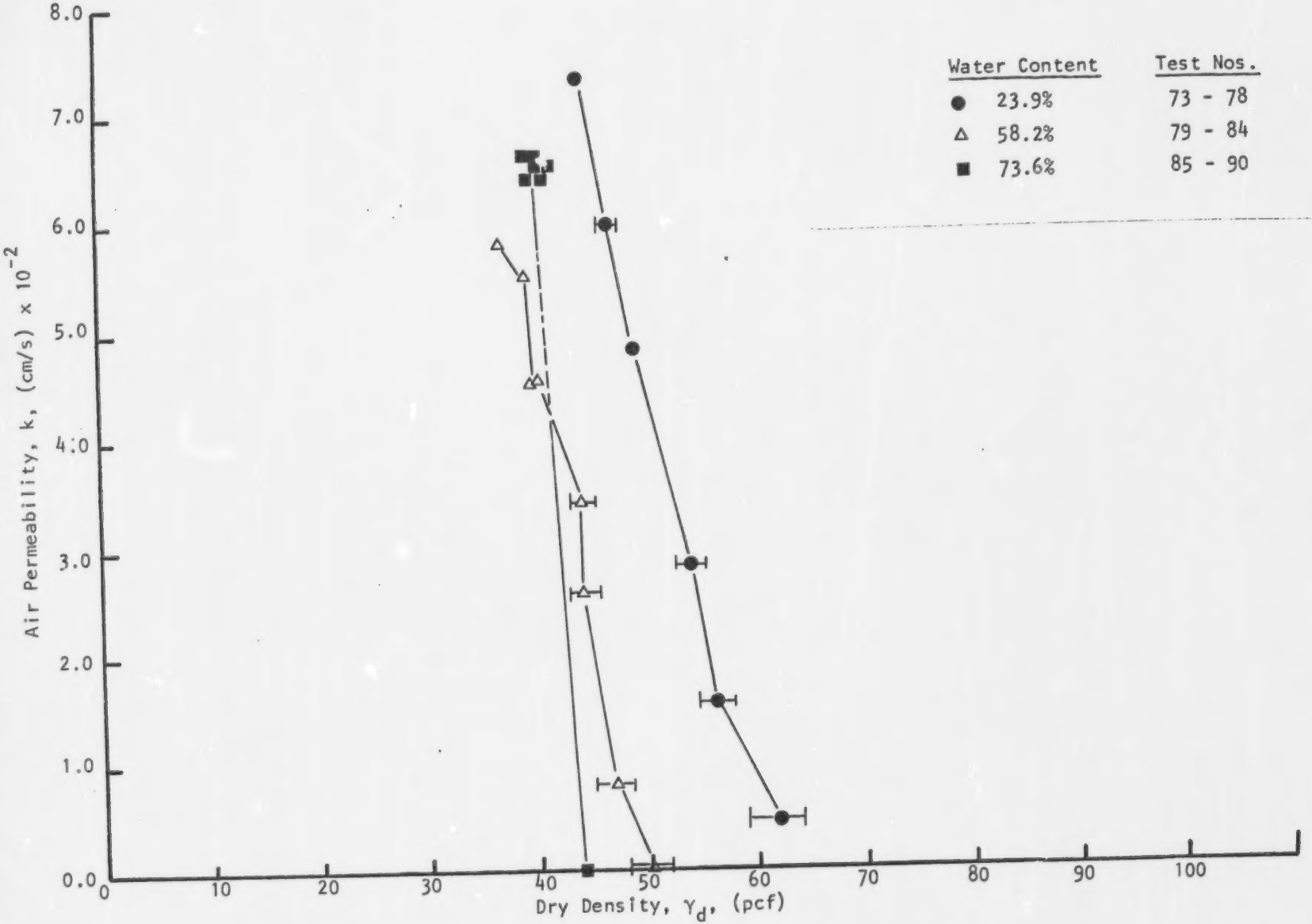

FIGURE NO. 18: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF DRY DENSITY FOR SMALL, COARSE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

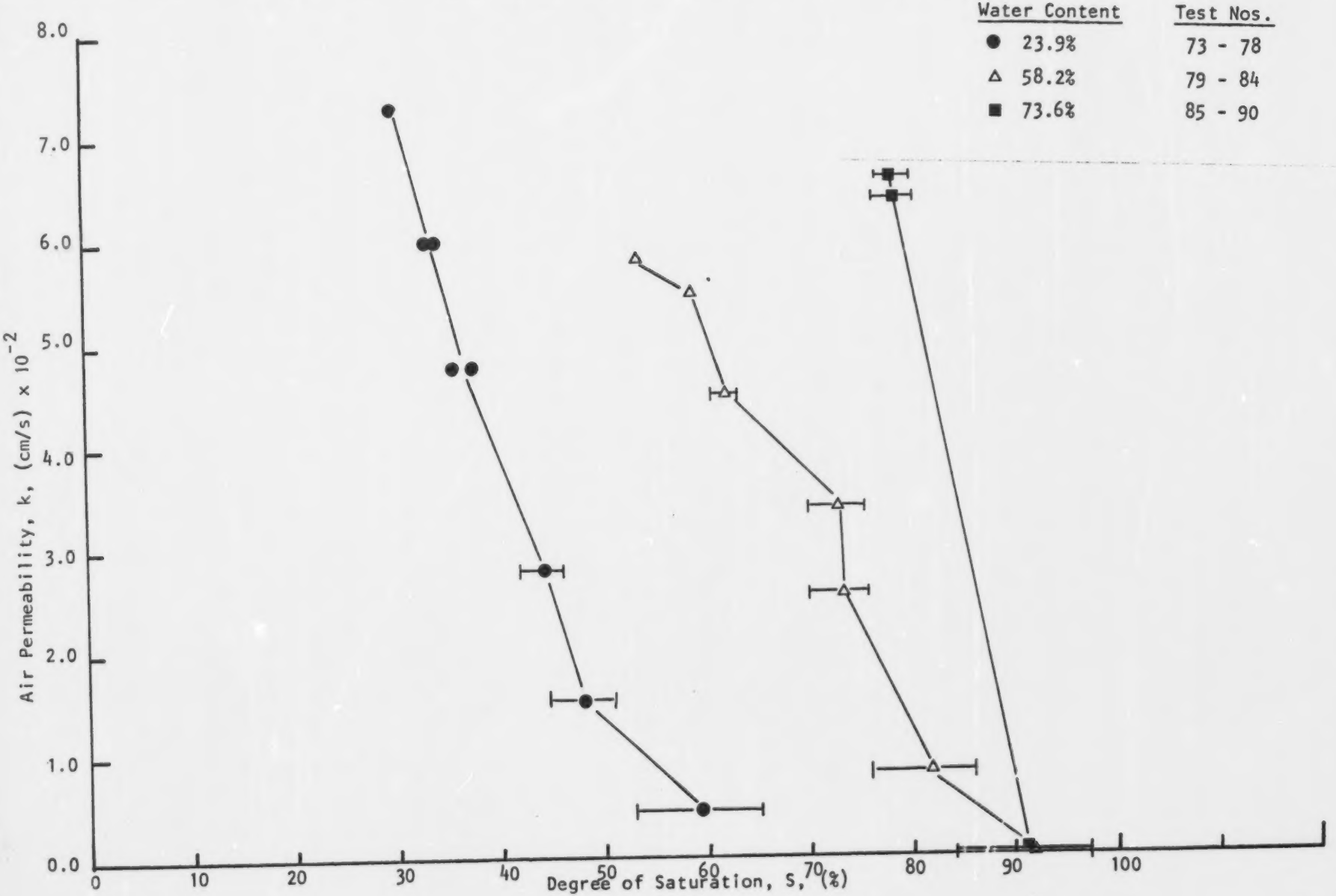

FIGURE NO. 19: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF THE DEGREE OF SATURATION FOR SMALL, COARSE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

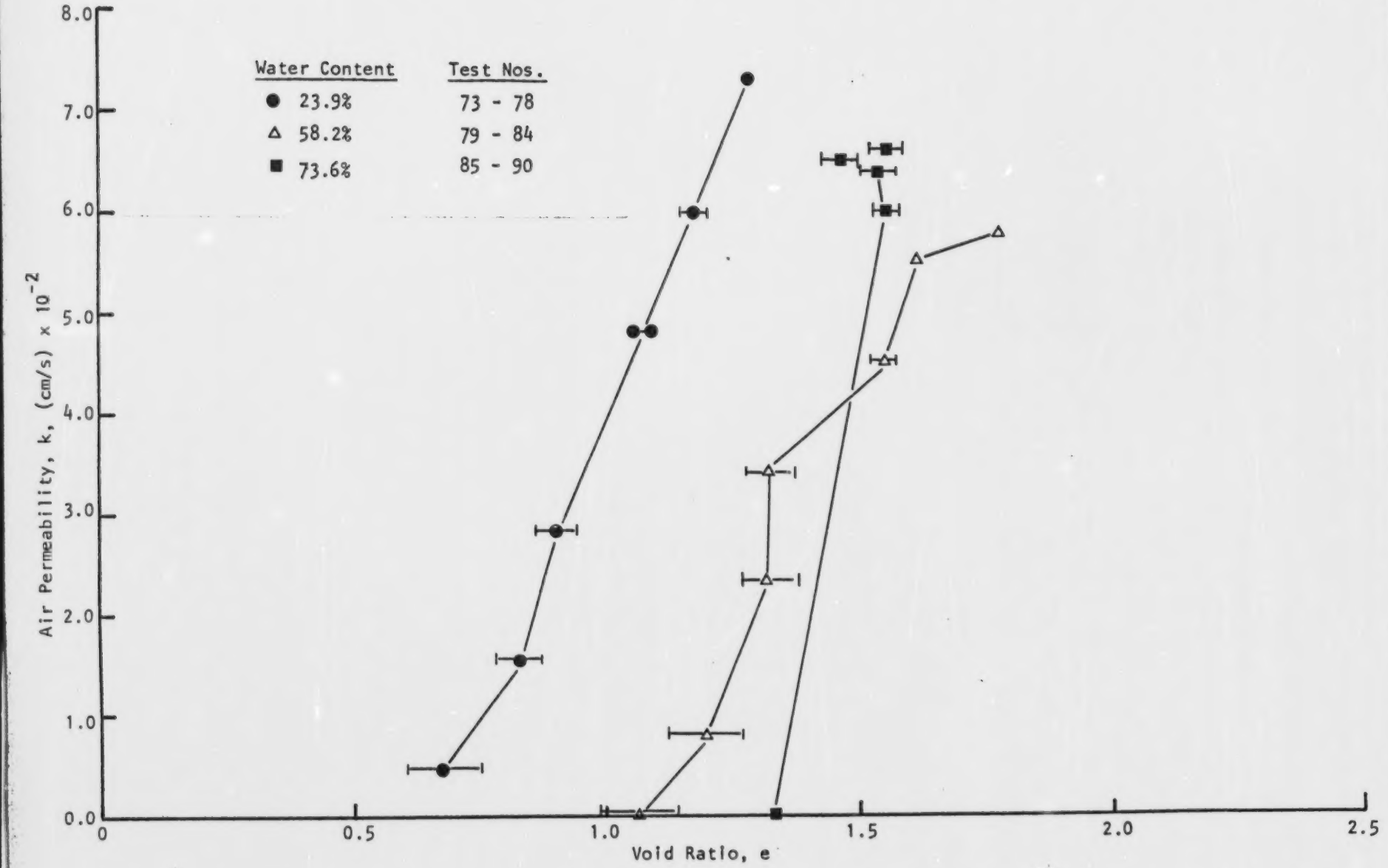

FIGURE NO. 20: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF VOID RATIO FOR SMALL, COARSE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

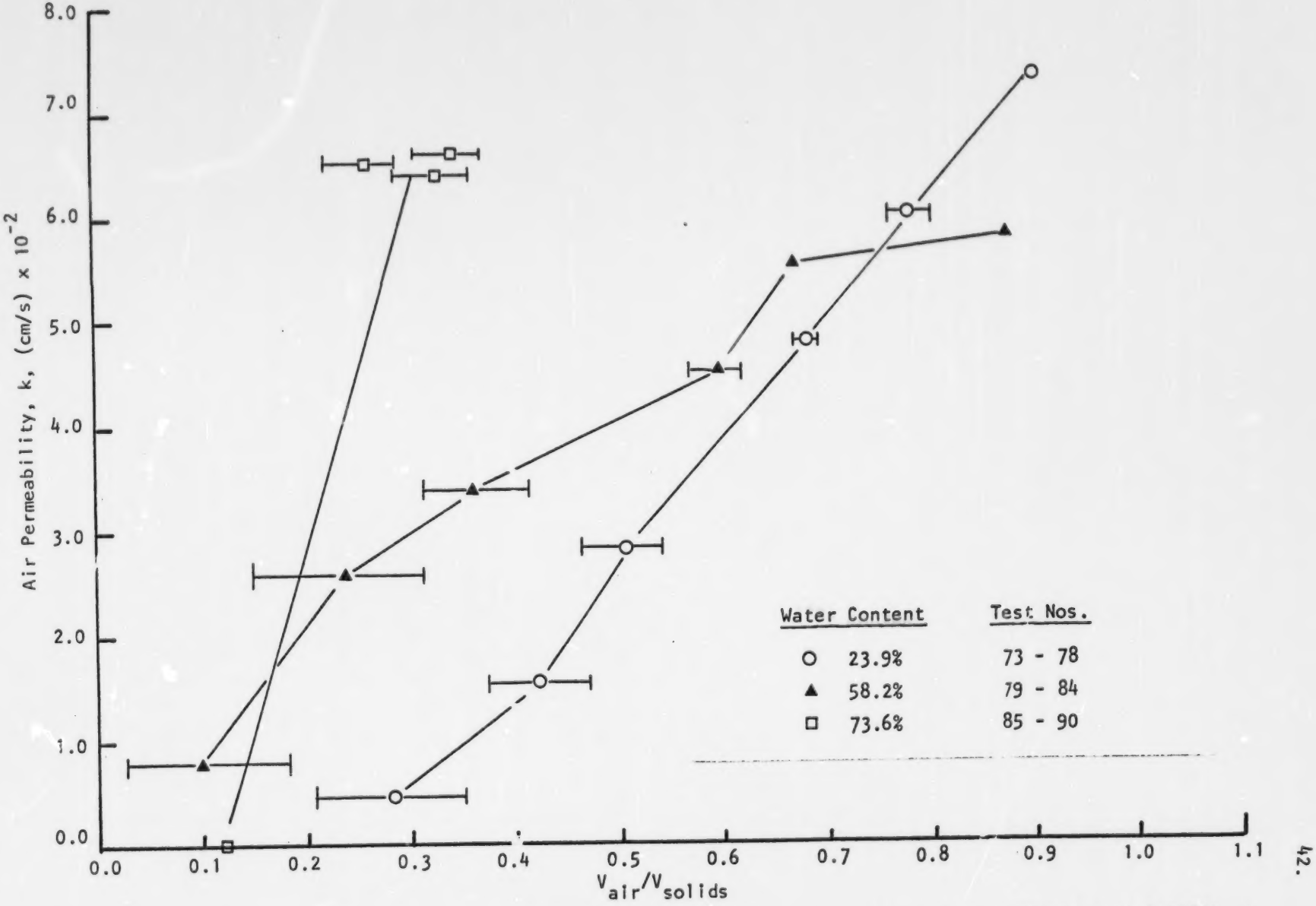

FIGURE NO. 21: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF $V_{air}V/_{solids}$ FOR SMALL, COARSE, INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

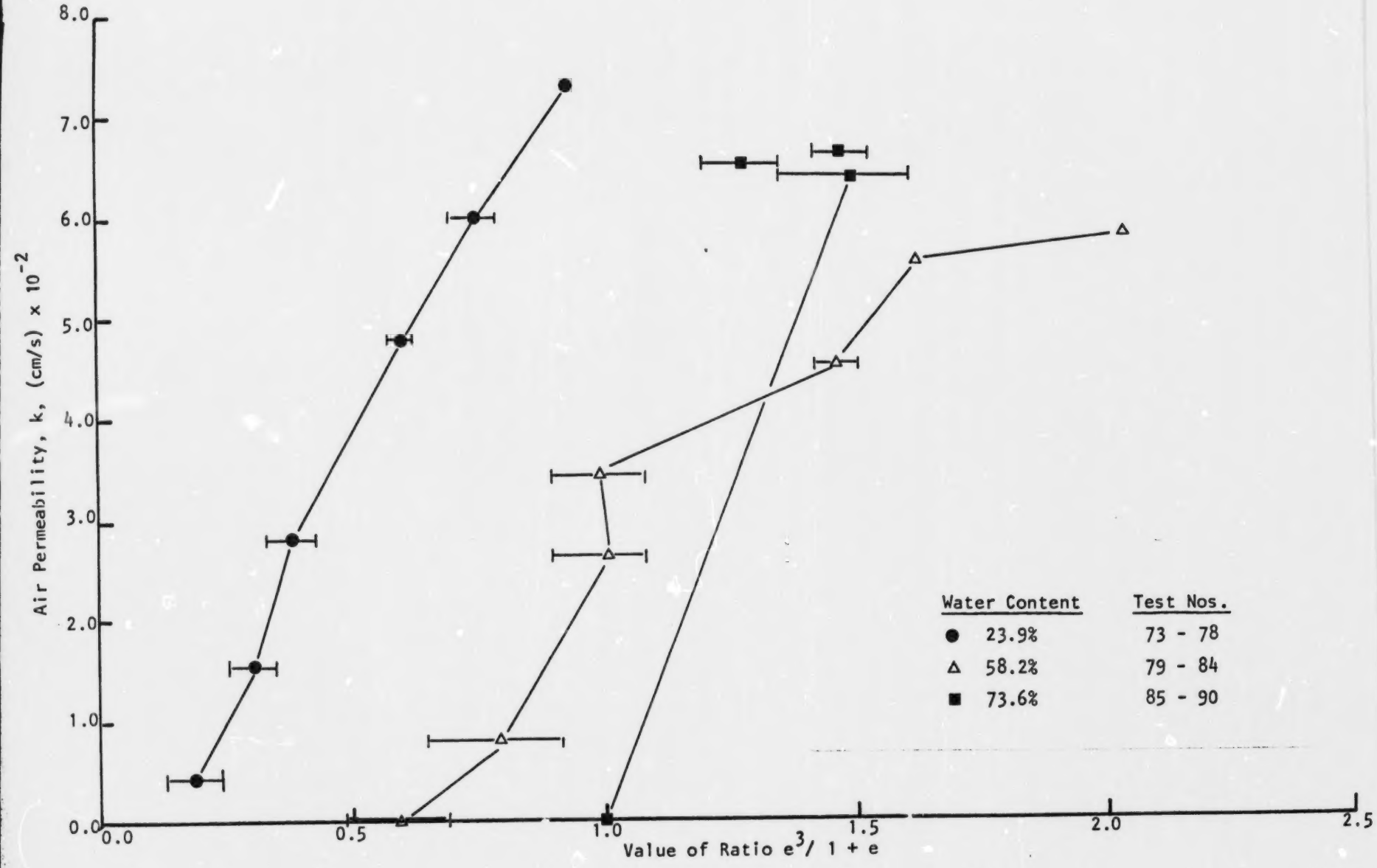

FIGURE NO. 22: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF $e^3/1 + e$ FOR SMALL, COARSE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

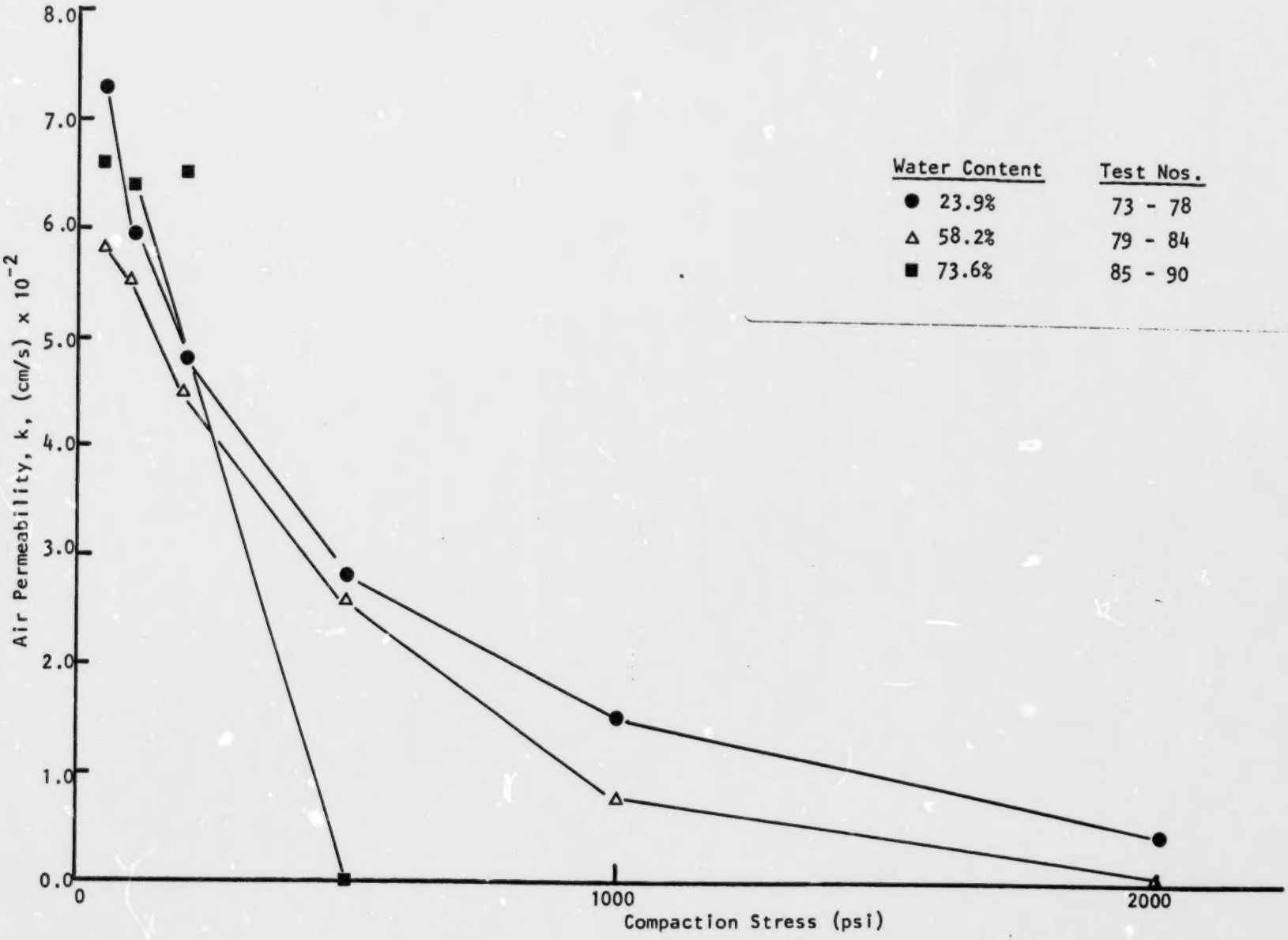

FIGURE NO. 23: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF COMPACTION STRESS LEVEL FOR SMALL, COARSE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

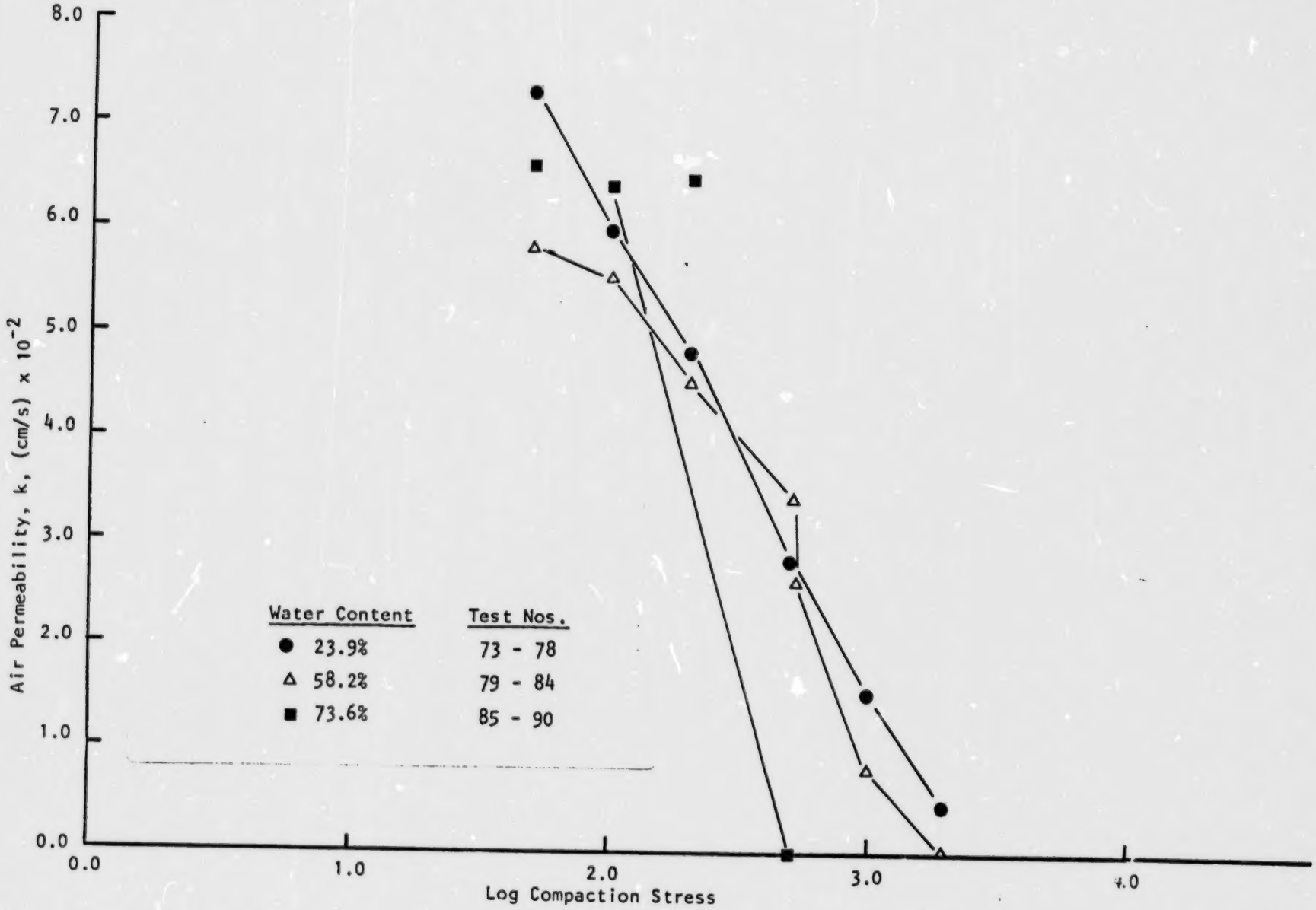

FIGURE NO. 24: VARIATION IN AIR PERMEABILITY AS A FUNCTION OF LOG COMPACTION STRESS LEVEL FOR SMALL, COARSE INCREMENTAL SAMPLES AT VARIOUS INITIAL WATER CONTENTS.

3.5.3 Practical Solution

In the previous section several selected parameters such as dry density and compaction stress were plotted as a function of the measured air permeability to see if there could be found a unique relationship. Unfortunately, this was not found.

Nevertheless, can the more practical question be answered, i.e.,

(1) Can one estimate the air permeability of a coal compact knowing the initial water content from a simple mechanical parameter such as dry density or compaction stress?

(2) Can one assess what level of density is required to produce a compact of minimal permeability?

and (3) Can one assess the compaction stress required to produce a compact of minimal permeability?

In Figures, Appendix C-1 to C-12, are presented the values of dry density and log compaction stress versus log air permeability for all of the incremental tests. Also shown in Figures 25 to 27 and 28 to 30 are the summary plots of log compaction stress and dry density versus log permeability for both fine and coarse coal at the three water content ranges.

In the previous section of this report a portion was devoted to discussing the problem of variability and the data in the summary seems to personify this theme.

In Figures 25 to 27, the summary plots for the fine coal samples, one can see that the trends between log compaction stress and log permeability are similar, but there is a tremendous difference in the permeability values.

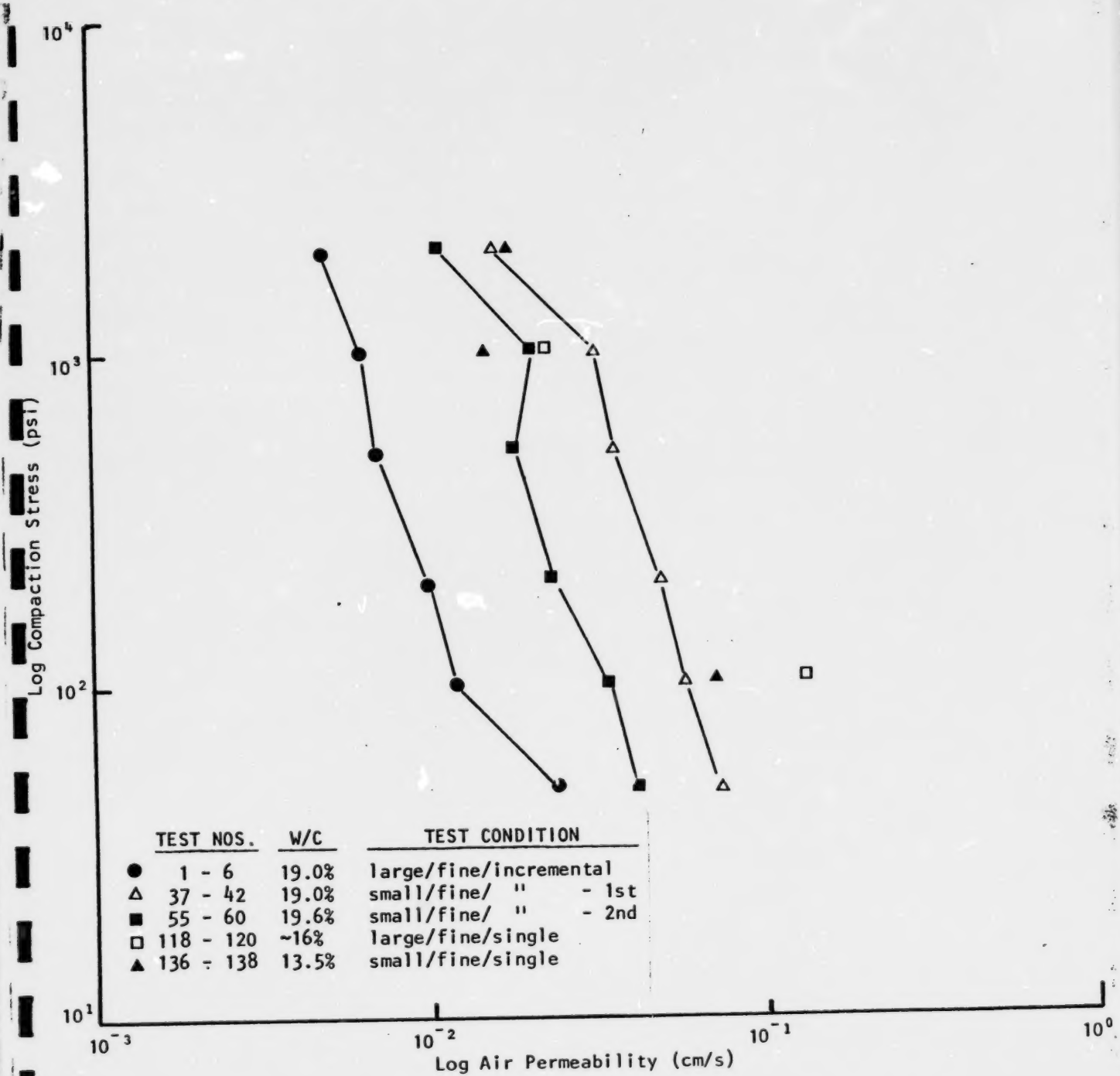

FIGURE NO. 25: SUMMARY OF INFLUENCE OF COMPACTION STRESS ON THE AIR PERMEABILITY FOR FINE COAL SAMPLES (~15% CONDITION).

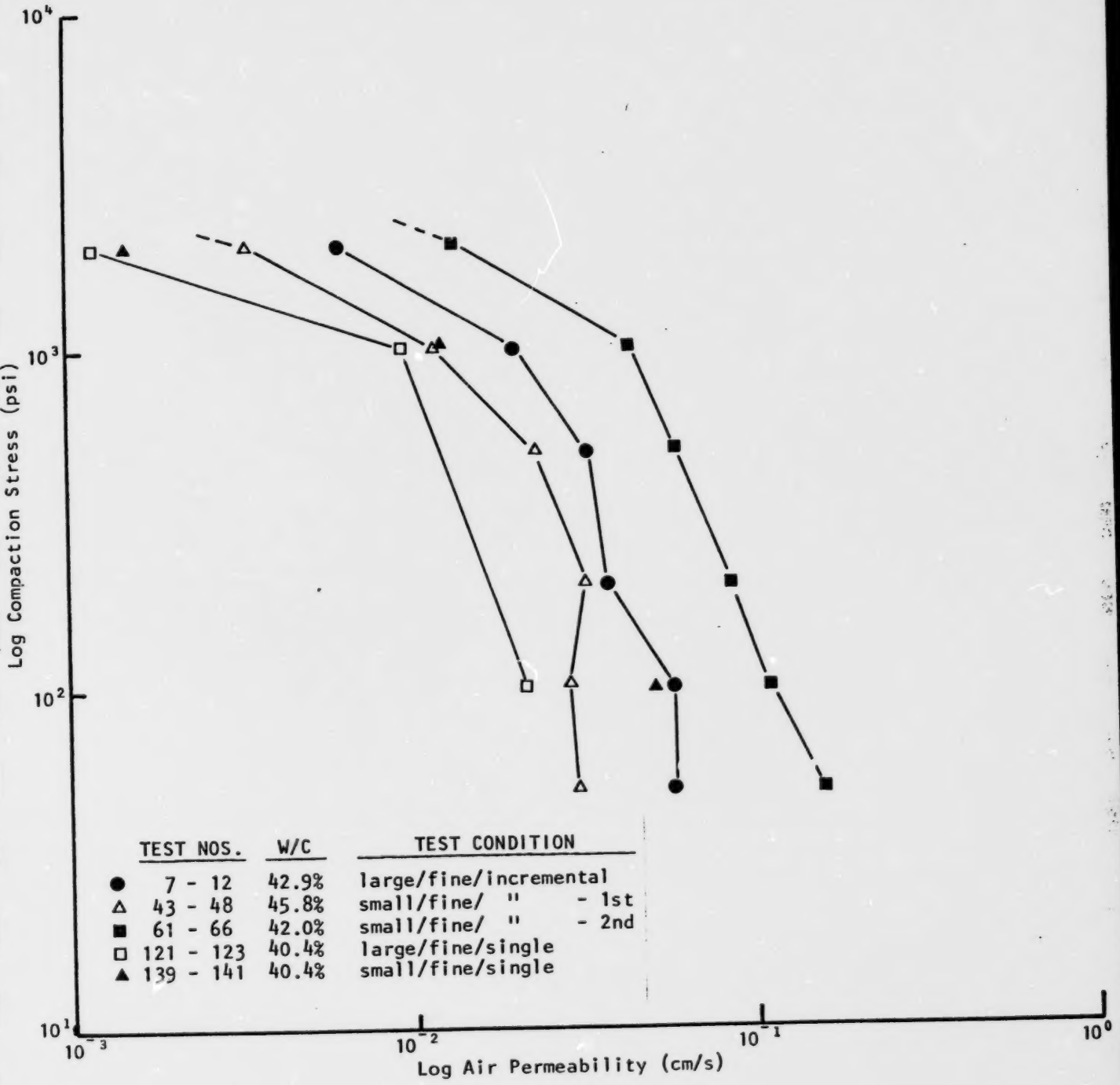

FIGURE NO. 26: SUMMARY OF INFLUENCE OF COMPACTION STRESS ON THE AIR PERMEABILITY FOR FINE COAL ("AS IS" CONDITION).

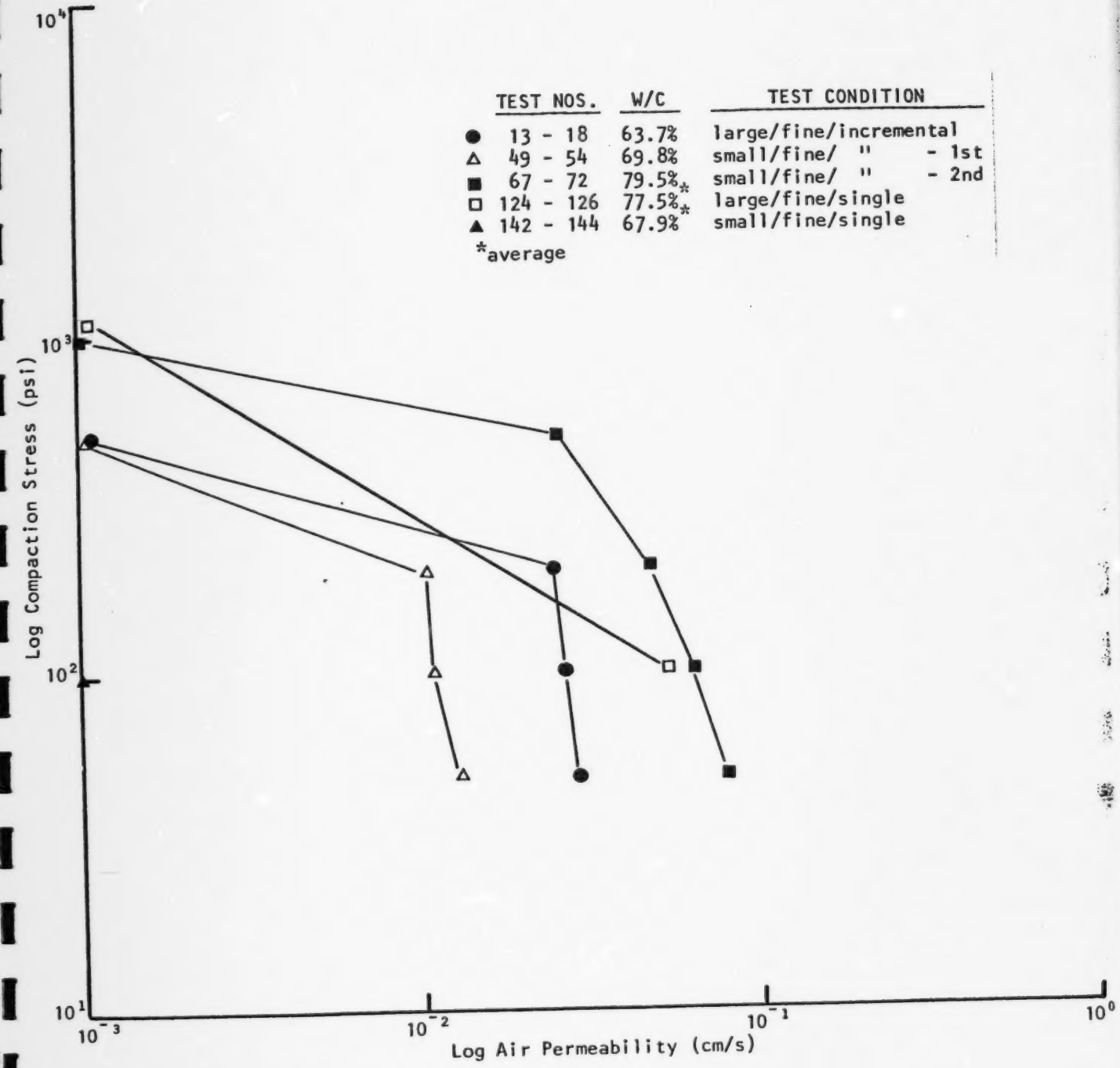

FIGURE NO. 27: SUMMARY OF INFLUENCE OF COMPACTION STRESS ON AIR PERMEABILITY OF FINE COAL (+10% CONDITION).

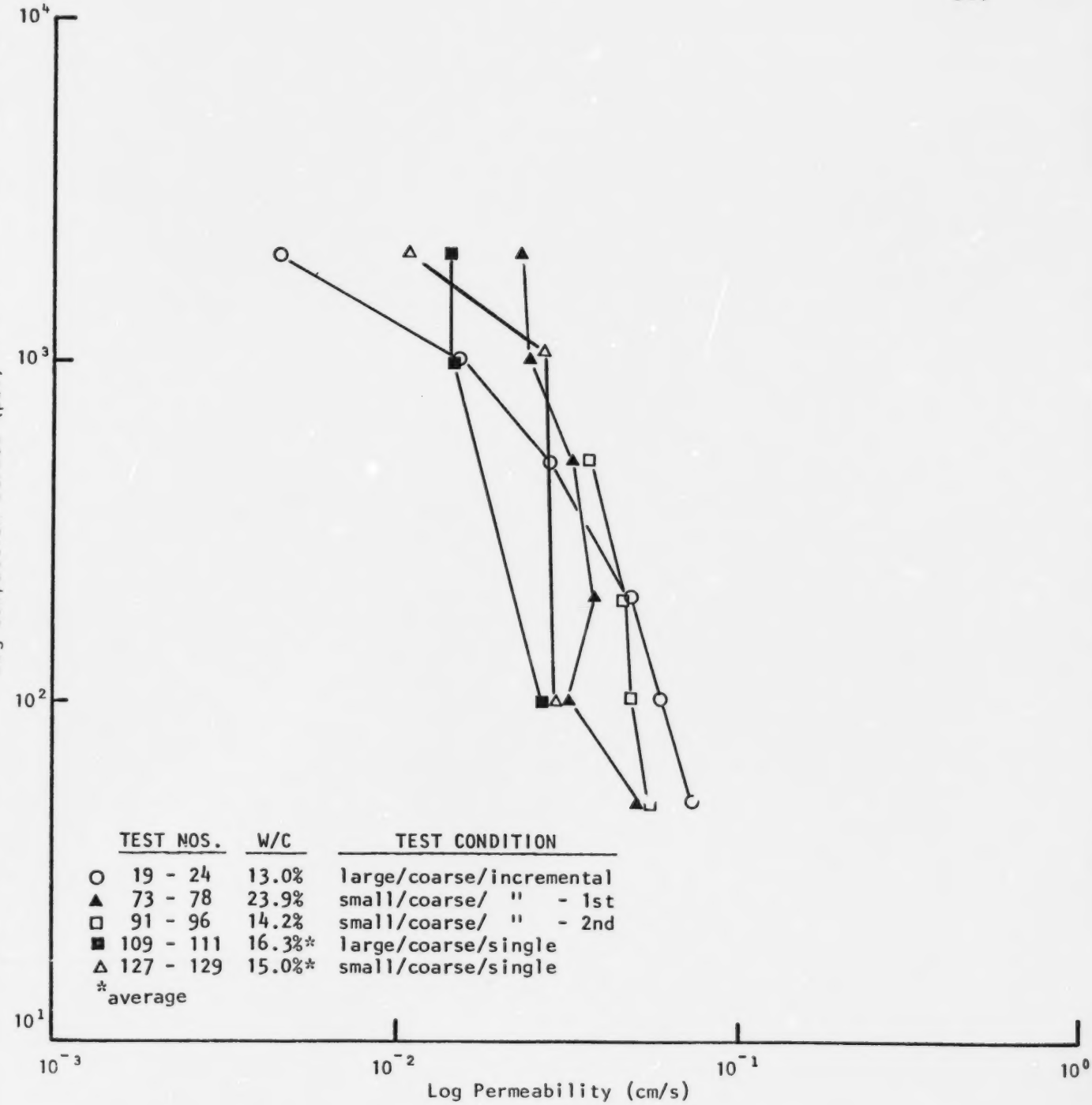

FIGURE NO. 28: SUMMARY OF INFLUENCE OF COMPACTION STRESS ON AIR PERMEABILITY OF COARSE COAL (~15% CONDITION).

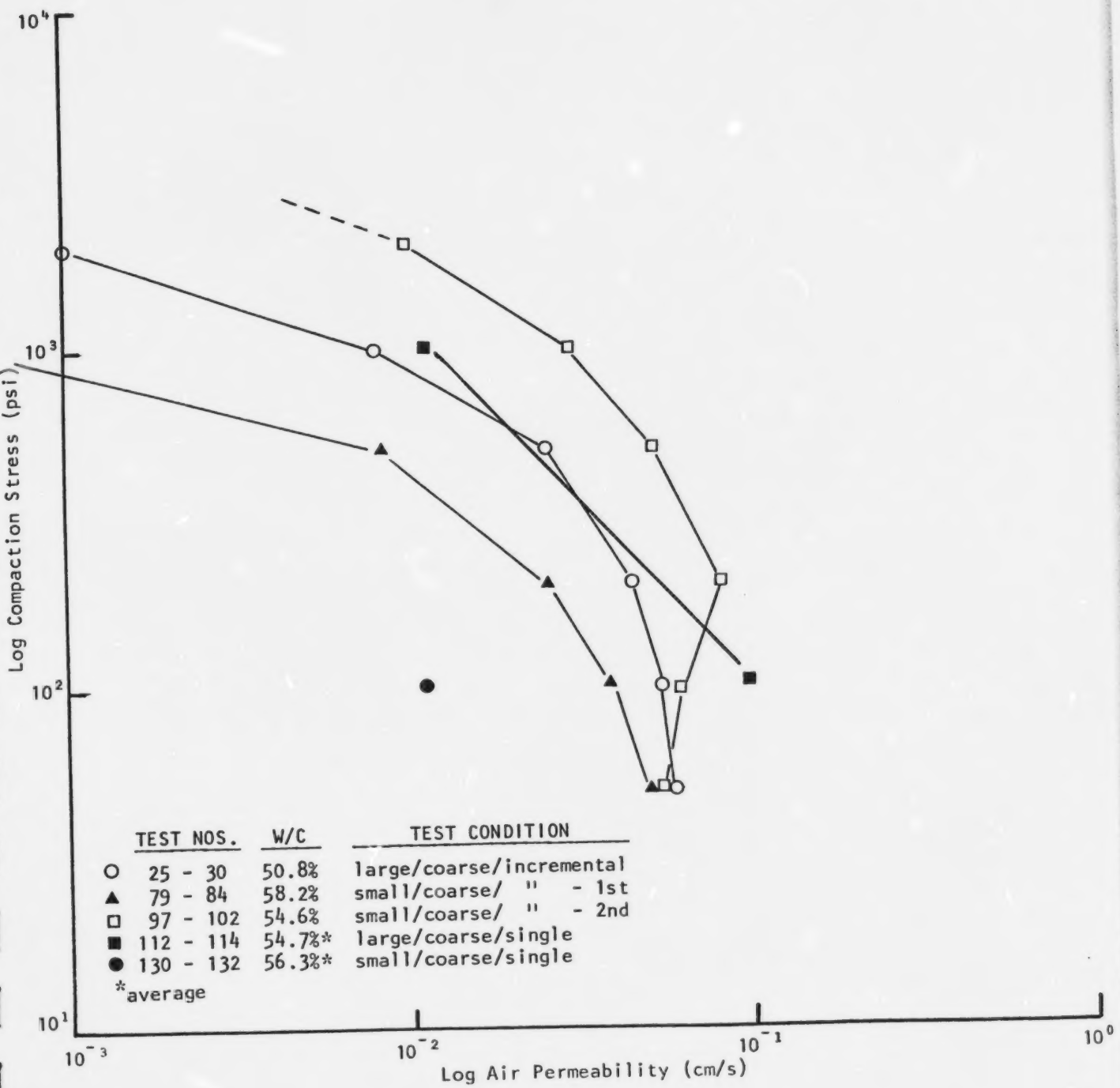

FIGURE NO. 29: SUMMARY OF INFLUENCE OF COMPACTION STRESS ON THE AIR PERMEABILITY FOR COARSE COAL SAMPLES ("AS IS" CONDITION).

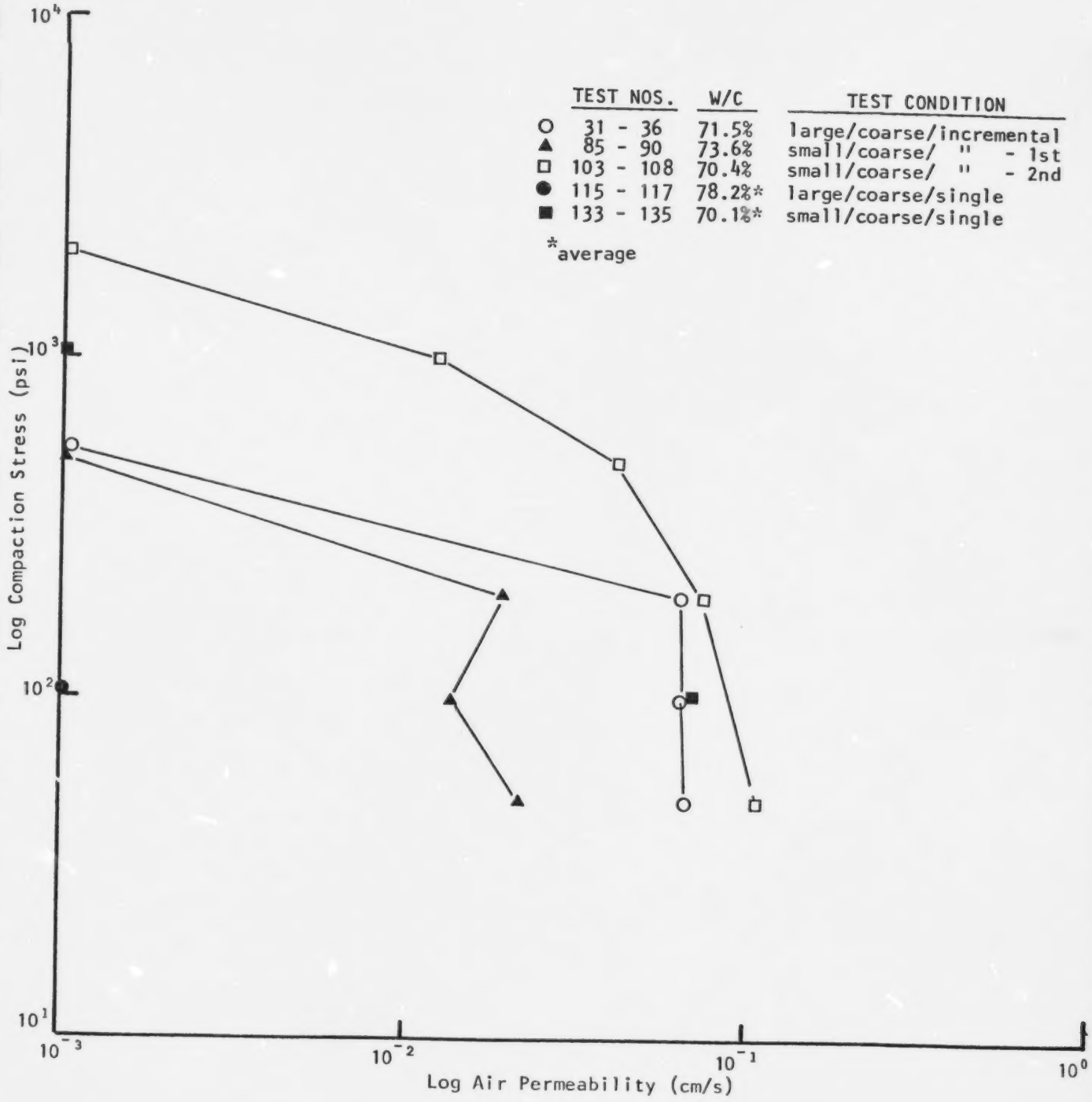

FIGURE NO. 30: SUMMARY OF INFLUENCE OF COMPACTION STRESS ON AIR PERMEABILITY OF COARSE COAL SAMPLES (+10% CONDITION).

This trend is similarly found for the coarse coal shown in Figures 28 to 30.

This problem of variability is a real one and well acknowledged and seems to be a paramount hurdle unless an extreme criteria is selected. As expected, the higher the initial water content the lower the compaction stress required to cause conditions of zero air permeability. The order of variation is in the order of one order of magnitude.

With respect to the Figures 31 to 36, which present the value of permeability as a function of dry density, the same randomness is seen with a variability in the order of 10 pounds per cubic foot (pcf).

It should be clearly stated that there is no real theoretical basis for assuming any real relationship between either the compaction stress or dry density and the permeability. The resultant structure of the compact is clearly a function of many facets, such as initial structure (fabric) of the cake, the water content, degree of saturation, etc. This is clearly a difficult problem and there is not likely to be a simple, invariable solution. For future work, it is hoped that this variability of the compact structure will be recognized as a major problem. It is felt that simulation of the real method of producing the coal compact is required as changing the conditions will inevitably change the permeability and its' variability.

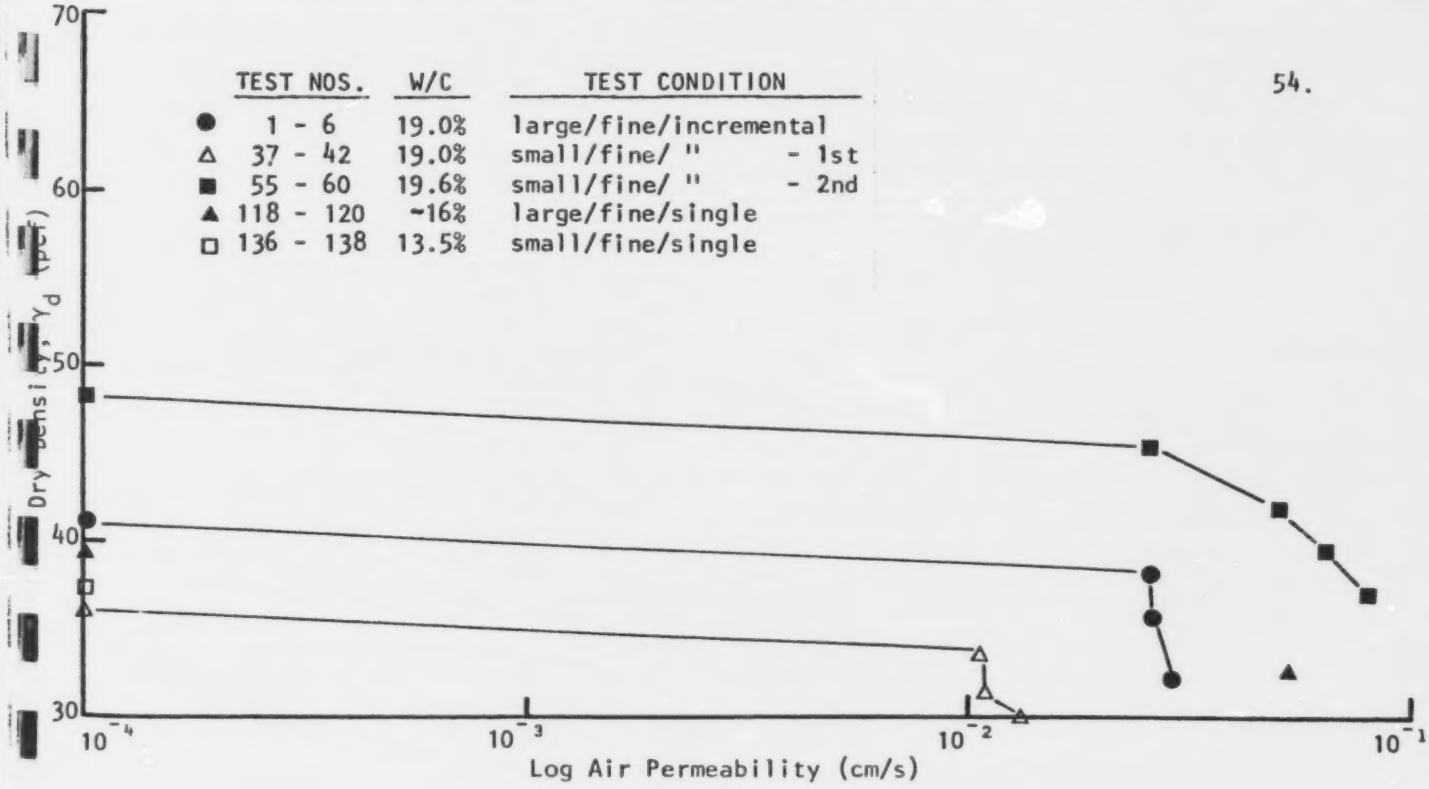

FIGURE NO. 31: SUMMARY OF INFLUENCE OF DRY DENSITY ON THE AIR PERMEABILITY FOR FINE COAL SAMPLES (+10% CONDITION).

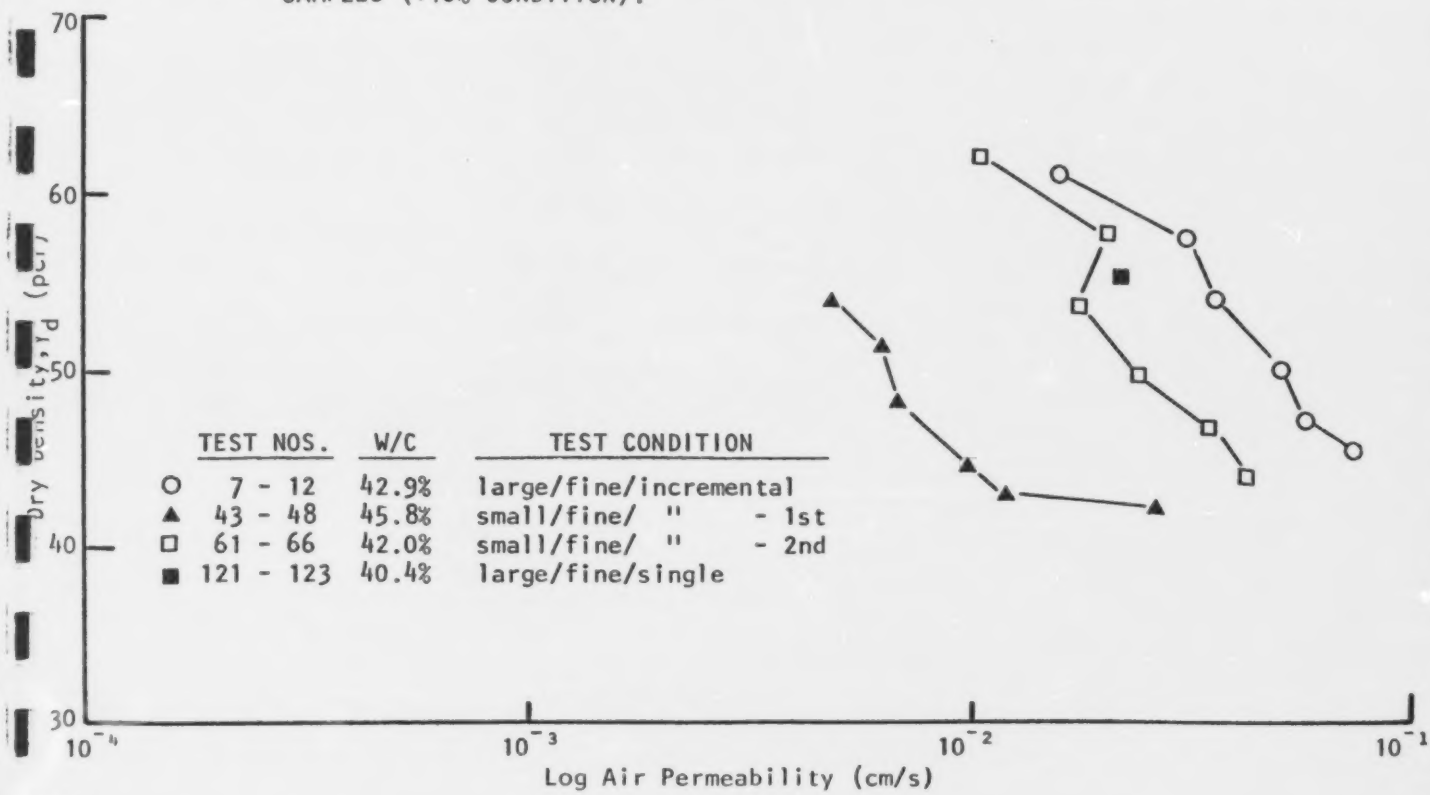

FIGURE NO. 32: SUMMARY OF INFLUENCE OF DRY DENSITY ON THE AIR PERMEABILITY FOR FINE COAL SAMPLES (~15% CONDITION).

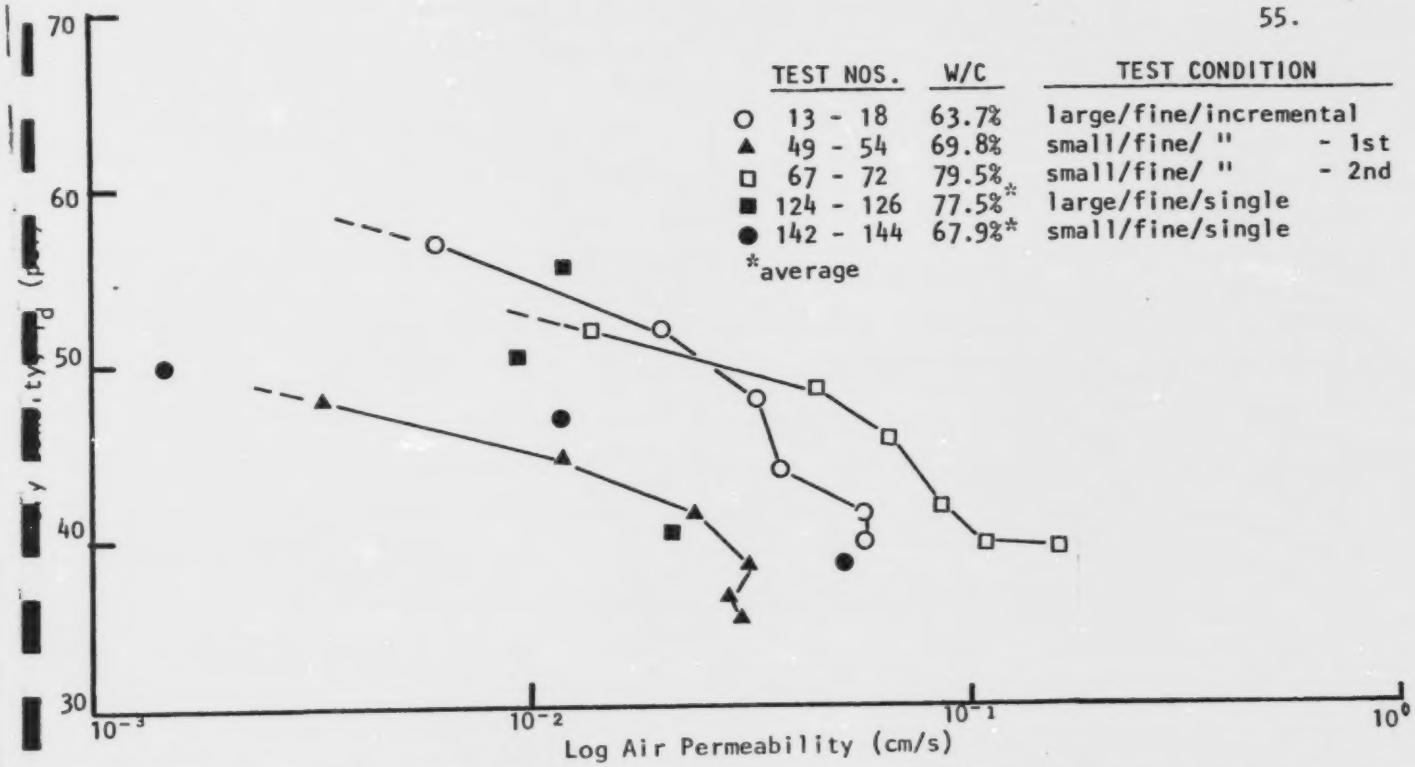

FIGURE NO. 33: SUMMARY OF INCLUFENCE OF DRY DENSITY ON THE AIR PERMEABILITY FOR FINE COAL SAMPLES ("AS IS" CONDITION).

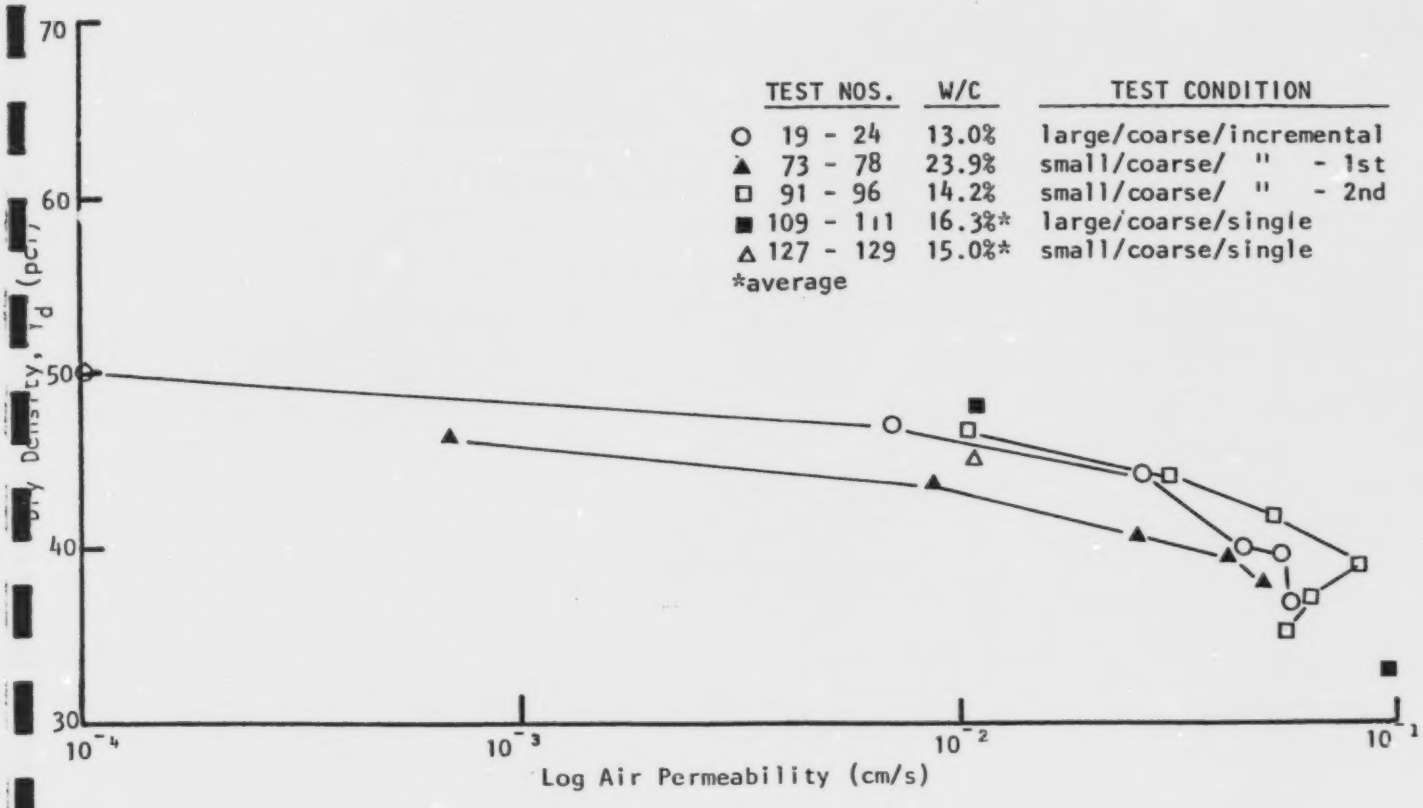

FIGURE NO. 34: SUMMARY OF INFLUENCE OF DRY DENSITY ON THE AIR PERMEABILITY FOR COARSE COAL SAMPLES ("AS IS" CONDITION).

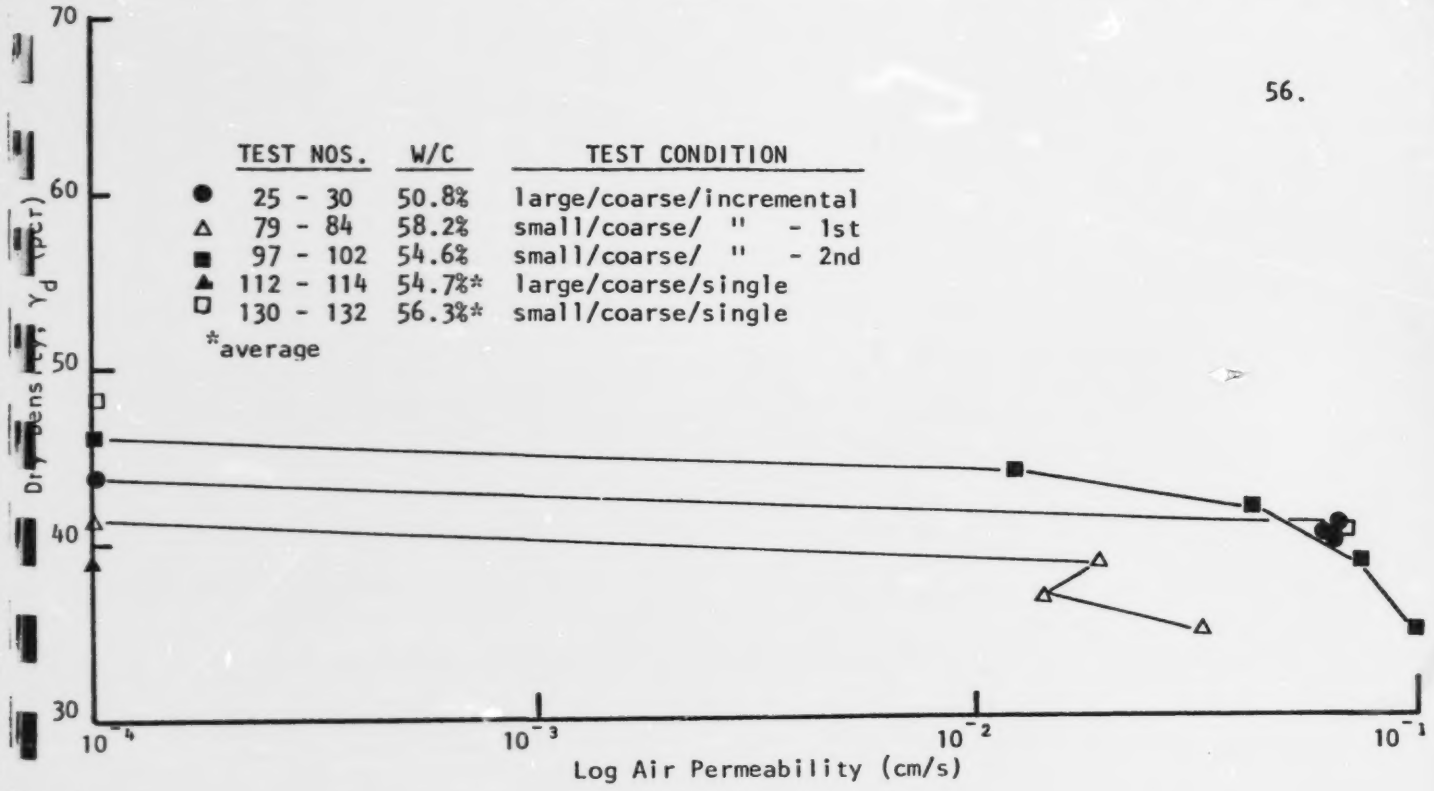

FIGURE NO. 35: SUMMARY OF INFLUENCE OF DRY DENSITY ON THE AIR PERMEABILITY FOR COARSE COAL SAMPLES (+10% CONDITION).

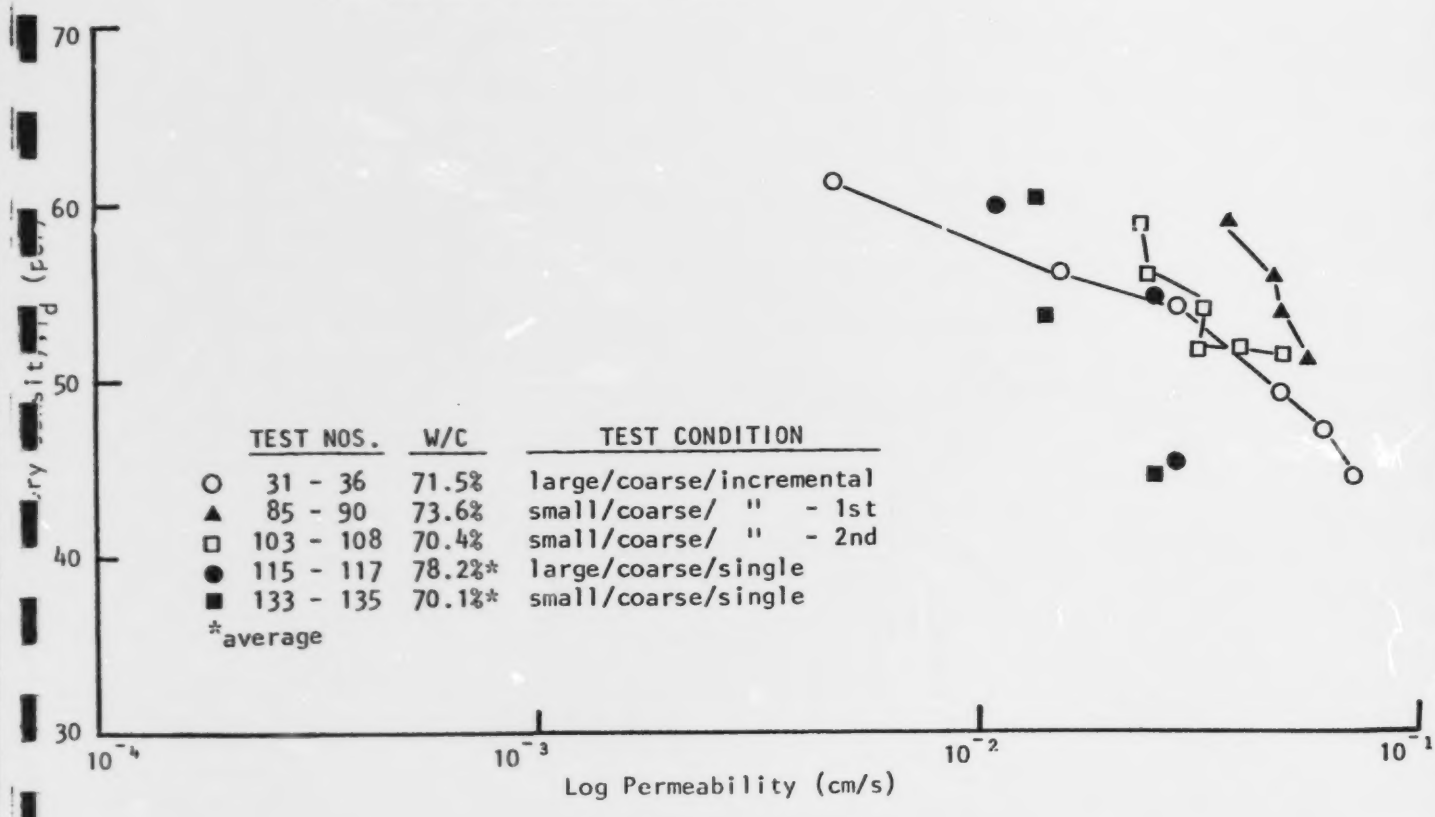

FIGURE NO. 36: SUMMARY OF INFLUENCE OF DRY DENSITY ON THE AIR PERMEABILITY FOR COARSE COAL SAMPLES (-15% CONDITION).

4.0 BLOW-OUT TESTS

4.1 Introduction

Blow-out tests were attempted on all of the 36 single level air permeability-compaction tests. Because of the unclearness of the real interpretation of 'blow out', i.e. the conditions which really describe this occurrence, a brief description is given of the observations made during each 'blow out' attempt.

4.2 Observations During Attempted Blow-out

1. Test #109 - large, coarse sample, compaction stress = 100 psi and moisture content = 14%.

It appeared that for this sample the blow-out occurred probably at 500 psi although only 400 psi was registered on the outflow line. After the blow-out the material at the top of the compact appeared still to be fairly firm, but at the bottom of the sample, next to the inflow pressure, a small crater was formed, the dimensions of which are shown in Figure 37. After turning the cylinder upside down twice the coal compact broke up and slipped out of the tube without further assistance.

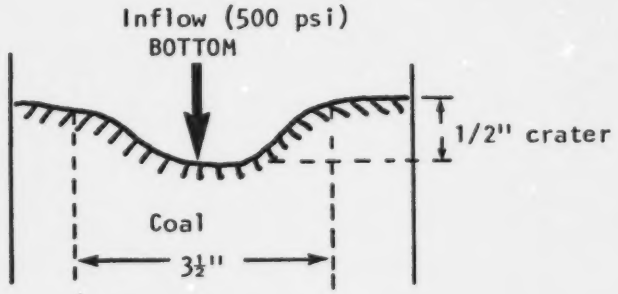

FIGURE NO. 37: LOCAL COMPACTION OR DISTURBANCE UNDER ATTEMPTED BLOW-OUT PRESSURE.

2. Test #110 - large, coarse sample, compaction stress = 1000 psi and moisture content = 14.5%

The observations during the blow-out test were similar to those seen in case (1) except the material was only loosen at the bottom of the compact whereas at the top it was still firm. A 600 psi supply pressure resulted in an outflow pressure of 400 psi. The description of the depression produced at the bottom of the sample is shown in Figure 38.

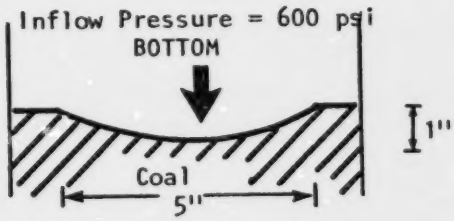

FIGURE NO. 38: LOCAL COMPACTION OR DISTURBANCE UNDER ATTEMPTED BLOW-OUT PRESSURE.

3. Test #111 - large, coarse sample, compaction stress = 2000 psi and moisture content = 13.6%

The supply air pressure was raised up to 1000 psi at which time the outflow pressure was measured at 550 psi. During this time no observable effects were seen as in case (1) and (2), such as crater formation at the bottom of the sample. Nevertheless removal of the coal compact from the cylinder required minimal mechanical assistance.

4. Test #127 - small, coarse sample, compaction stress = 100 psi and moisture content = 12.6%

The air pressure was raised up to 900 psi and 810 psi was measured at the outflow side of the sample. Total blow-out was achieved with all the material being visibly loosened.

5. Test #128 - small, coarse sample, compaction stress = 1000 psi and moisture content = 13.4%

On raising the air pressure up to 800 psi, 700 psi was registered on the outflow side of the sample. Only approximately 1" of the top surface coal was loosened. At the base a small depression was formed as shown in Figure 39.

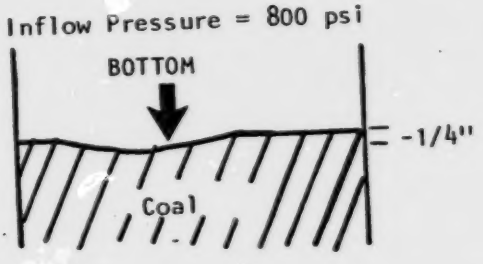

FIGURE NO. 39: LOCAL COMPACTION OR DISTURBANCE UNDER ATTEMPTED BLOW-OUT PRESSURE.

6. Test #129 - small, coarse sample, compaction stress = 2000 psi and moisture content = 13.3%

At an inflow pressure of 680 psi, the outflow pressure was measured at 610 psi. It appeared no blow-out was achieved with only the top 1/2" of the coal loosened. At the bottom a small, but deep crater was formed, as shown in Figure 40.

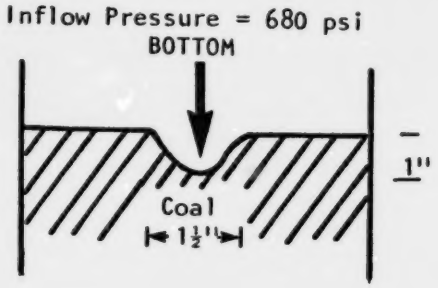

FIGURE NO. 40: LOCAL COMPACTION OR DISTURBANCE UNDER ATTEMPTED BLOW-OUT PRESSURE.

7. Test #130 - small, coarse sample, compaction stress = 100 psi and moisture content = 35.3%.

After increasing the air pressure up to 500 psi, 400 psi was registered at the top surface of the sample. A fairly large depression was formed at the bottom whereas only about 2" of loosened material was observed at the top. The dimensions of the bottom crater are shown in Figure 41.

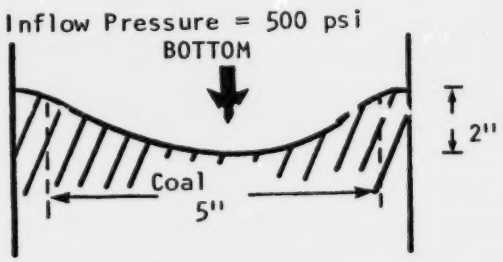

FIGURE NO. 41: LOCAL COMPACTION OR DISTURBANCE UNDER ATTEMPTED BLOW-OUT PRESSURE.

8. Test #131 - small, coarse sample, compaction stress = 1000 psi and moisture content = 35.8%

The inflow pressure was increased up to 1100 psi, 1000 psi being measured at the outflow side.

9. Test #140 - small, fine coal sample, compaction stress = 1000 psi and moisture content = 28.8%

The applied air pressure was raised up to 1500 psi (1400 psi being registered on the outflow side). There was very little difference in the texture of the coal compact between before and after, and only a very small amount of loosened coal at the bottom of the sample.

10. Test #141 - small, fine coal sample, compaction stress = 2000 psi amd moisture content = 28.8%

The supply pressure was increased up to 800 psi with 600 psi being measured on the outflow side. No differences were observed in sample before or after the supplied pressure was applied.

11. Test #121 - large, fine coal sample, compaction stress = 100 psi and moisture content = 28.8%

On increasing the air supply pressure up to 600 psi, only 350 psi was registered on the outflow side. A crater was formed at the bottom surface as shown in Figure 42 and about 3" of coal was loosened at the top surface. On removing the sample from the cylinder it was found that the rest of the material had been loosened as very little mechanical assistance was required.

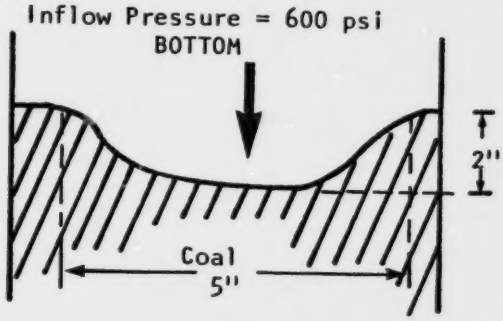

FIGURE NO. 42: LOCAL COMPACTION OR DISTURBANCE UNDER ATTEMPTED BLOW-OUT PRESSURE.

12. Test #122:- large, fine coal sample, compaction stress = 1000 psi and moisture content = 28.8%

On supplying an air pressure of 700 psi to the bottom of the sample, the outflow pressure was measured at 400 psi. The top of the coal sample was loosened to a depth of approximately 2". The bottom had a small depression as shown in Figure 43.

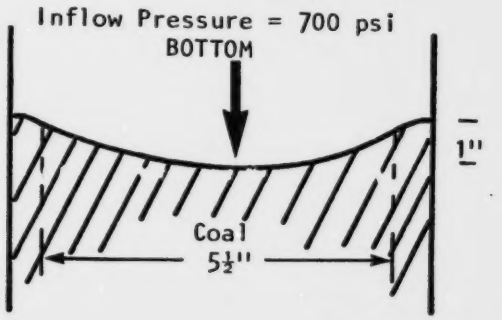

FIGURE NO. 43: LOCAL COMPACTION OR DISTURBANCE UNDER ATTEMPTED BLOW-OUT PRESSURE.

13. Test #123 - large, fine coal sample, compaction stress = 2000 psi and moisture content = 28.8%

The supplied air pressure was raised up to 900 psi which resulted in an outflow pressure of 400 psi. This large difference in pressure is probably not due to head loss, but to a certain amount of leakage (observed). After the application of the 900 psi only the top 2" of the

coal appeared to be loosened; the rest being still compact. The dimensions of the depression made into the bottom of the sample are shown in Figure 44.

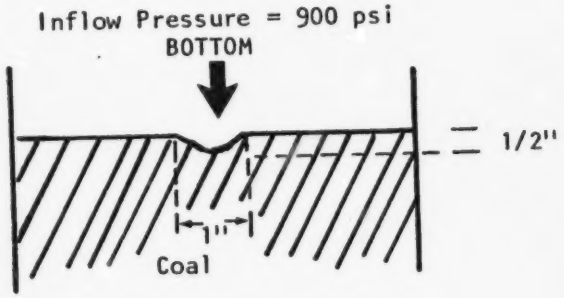

FIGURE NO. 44: LOCAL COMPACTION OR DISTURBANCE UNDER ATTEMPTED BLOW-OUT PRESSURE.

APPENDIX "A"

BASIC EXPERIMENTAL DATA

— Tables of Flow Rate against Applied Air Pressure Level

— Figures of Applied Air Pressue versus Flow Rate

TABLE A-1: COMPLETE TEST FORMAT

TEST NO.	COMPACTION STRESS
Tests #1-6, Large Sample, Fine Coal, Incremental Moisture Content = 16%	
1	50 psi
2	100 psi
3	200 psi
4	500 psi
5	1000 psi
6	2000 psi
Tests #7-12, Large Sample, Fine Coal, Incremental Moisture Content = 30%	
7	50 psi
8	100 psi
9	200 psi
10	500 psi
11	1000 psi
12	2000 psi
Tests #13-18, Large Sample, Fine Coal, Incremental Moisture Content = 38.9%	
13	50 psi
14	100 psi
15	200 psi
16	500 psi
17	1000 psi*
18	2000 psi*
Tests #19-24, Large Sample, Coarse Coal, Incremental Moisture Content = 11.5%	
19	50 psi
20	100 psi
21	200 psi
22	500 psi
23	1000 psi
24	2000 psi
Tests #25-30, Large Sample, Coarse Coal, Incremental Moisture Content = 33.7%	
25	50 psi
26	100 psi
27	200 psi
28	500 psi
29	1000 psi
30	2000 psi
Tests #31-36, Large Sample, Coarse Coal, Incremental Moisture Content = 41.7%	
31	50 psi
32	100 psi
33	200 psi
34	500 psi
35	1000 psi
36	2000 psi*

*Sample saturated, zero permeability.

Table A-1: Complete Test Format continued . . .

TEST NO.	COMPACTION STRESS
Tests #37-42, Small Sample, Fine Coal, Incremental, 1st series Moisture Content = 15%	
37	50 psi
38	100 psi
39	200 psi
40	500 psi
41	1000 psi
42	2000 psi

TEST NO.	COMPACTION STRESS
Tests #43-48, Small Sample, Fine Coal, Incremental, 1st series Moisture Content = 31.4%	
43	50 psi
44	100 psi
45	200 psi
46	500 psi
47	1000 psi
48	2000 psi

Tests #49-54, Small Sample, Fine Coal, Incremental, 1st series Moisture Content = 41.1%	
49	50 psi
50	100 psi
51	200 psi
52	500 psi*
53	1000 psi*
54	2000 psi*

*Sample saturated, zero permeability.

Tests #55-60, Small Sample, Fine Coal, Incremental, 2nd series Moisture Content = 16.4%	
55	50 psi
56	100 psi
57	200 psi
58	500 psi
59	1000 psi
60	2000 psi

Tests #61-66, Small Sample, Fine Coal, Incremental, 2nd series Moisture Content = 29.6%	
61	50 psi
62	100 psi
63	200 psi
64	500 psi
65	1000 psi
66	2000 psi

Tests #67-72, Small Sample, Fine Coal, Incremental, 2nd series Moisture Content = 44.3%	
67	50 psi
68	100 psi
69	200 psi
70	500 psi*
71	1000 psi*
72	2000 psi*

*Sample saturated, zero permeability.

Table A-1: Complete Test Format continued . . .

TEST NO.	COMPACTION STRESS
Tests #73-78, Small Sample, Coarse Coal, Incremental, 1st series Moisture Content = 19.3%	
73	50 psi
74	100 psi
75	200 psi
76	500 psi
77	1000 psi
78	2000 psi
Tests #79-84, Small Sample, Coarse Coal, Incremental, 1st series Moisture Content = 36.8%	
79	50 psi
80	100 psi
81	200 psi
82	500 psi
83	1000 psi
84	2000 psi*
Tests #85-90, Small Sample, Coarse Coal, Incremental, 1st series Moisture Content = 42.4%	
85	50 psi
86	100 psi
87	200 psi
88	500 psi*
89	1000 psi*
90	2000 psi*
Tests #91-96, Small Sample, Coarse Coal, Incremental, 2nd series Moisture Content = 12.4%	
91	50 psi
92	100 psi
93	200 psi
94	500 psi
95	N/A
96	N/A
Tests #97-102, Small Sample, Coarse Coal, Incremental, 2nd series Moisture Content = 35.3%	
97	50 psi
98	100 psi
99	200 psi
100	500 psi
101	1000 psi
102	2000 psi
Tests #103-108, Small Sample, Coarse Coal, Incremental, 2nd series Moisture Content = 41.3%	
103	50 psi
104	100 psi
105	200 psi
106	500 psi*
107	1000 psi*
108	2000 psi*

*Sample saturated, zero permeability.

N/A = not attempted

Table A-1: Complete Test Format continued . . .

TEST NO.	MOISTURE CONTENT	COMPACTION STRESS
Tests #109-111, Large Sample, Coarse Coal, Single Level		
109	14.0%	100 psi
110	14.5%	1000 psi
111	13.6%	2000 psi
Tests #115-117, Large Sample, Coarse Coal, Single Level		
115	42.0%	100 psi*
116	41.5%	1000 psi*
117	46.1%	2000 psi*
Tests #121-123, Large Sample, Fine Coal, Single Level		
121	28.8%	100 psi
122	28.8%	1000 psi
123	28.8%	2000 psi
Tests #127-129, Small Sample, Coarse Coal, Single Level		
127	12.6%	100 psi
128	13.4%	1000 psi
129	13.3%	2000 psi
Tests #133-135, Small Sample, Coarse Coal, Single Level		
133	42.1%	100 psi
134	41.0%	1000 psi
135	40.3%	2000 psi

TEST NO.	MOISTURE CONTENT	COMPACTION STRESS
Tests #112-114, Large Sample, Coarse Coal, Single Level		
112	36.2%	100 psi
113	34.5%	1000 psi
114	36.1%	2000 psi*
Tests #118-120, Large Sample, Fine Coal, Single Level		
118	~14.0%	100 psi
119	~14.0%	1000 psi
120	~14.0%	2000 psi
Tests #124-126, Large Sample, Fine Coal, Single Level		
124	44.3%	100 psi
125	44.1%	1000 psi
126	42.9%	2000 psi
Tests #130-132, Small Sample, Coarse Coal, Single Level		
130	35.3%	100 psi
131	35.8%	1000 psi
132	36.6%	2000 psi
Tests #136-138, Small Sample, Fine Coal, Single Level		
136	13.5%	100 psi
137	15.8%	1000 psi
138	12.0%	2000 psi

*Sample saturated, zero permeability.

Table A-1: Complete Test Format continued . . . .

TEST NO.	MOISTURE CONTENT	COMPACTION STRESS
Tests #139-141, Small Sample, Fine Coal, Single Level		
139	28.8%	100 psi
140	28.8%	1000 psi
141	28.8%	2000 psi

TEST NO.	MOISTURE CONTENT	COMPACTION STRESS
Tests #142-144, Small Sample Fine Coal, Single Level		
142	41.0%	100 psi
143	40.1%	1000 psi
144	39.9%	2000 psi

TABLE A-2: AIR PERMEABILITY DATA FOR TEST #1 - 6

COAL DESCRIPTION: Large Fine, Incremental

MOISTURE CONTENT:

Initial = 16%

WEIGHT OF SAMPLE = 10.87 lbs.

AREA = 28.0 sq.in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.0	0.0	0.0	0.0
12.8 - 12.9	50	5	3.6
		10	7.2
		15	8.9
		20	10.9
		25	12.9
		30	13.8
		35	15.6
		40	15.9
		45	16.7
		50	18.6
12.0 - 12.2	100	10	5.0
		15	6.9
		20	8.4
		25	10.2
		30	11.4
		35	12.9
		40	15.3
		50	19.0
		70	23.7
11.3 - 11.5	200	10	5.7
		20	10.2
		30	13.8
		40	16.7
		50	19.2
		60	22.0
		70	24.0
		95	29.2

Continued . . . . . .

Air Permeability data for tests #1 - 6 continued. . .

WEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
10.4 - 10.8	500	10	3.4
		20	6.9
		30	10.2
		40	12.4
		50	14.6
		60	16.4
		70	18.4
		95	21.4
		145	29.8
9.6 - 10.8	1000	10	2.2
		20	5.0
		30	7.4
		40	10.4
		50	12.4
		60	14.6
		70	17.5
		95	24.0
		145	33.7
8.8 - 9.4	2000	20	1.6
		30	2.2
		40	3.4
		50	4.7
		60	6.4
		70	7.9
		85	9.9
		95	11.1
		115	14.3
		145	18.4
		195	25.9
		245	33.1

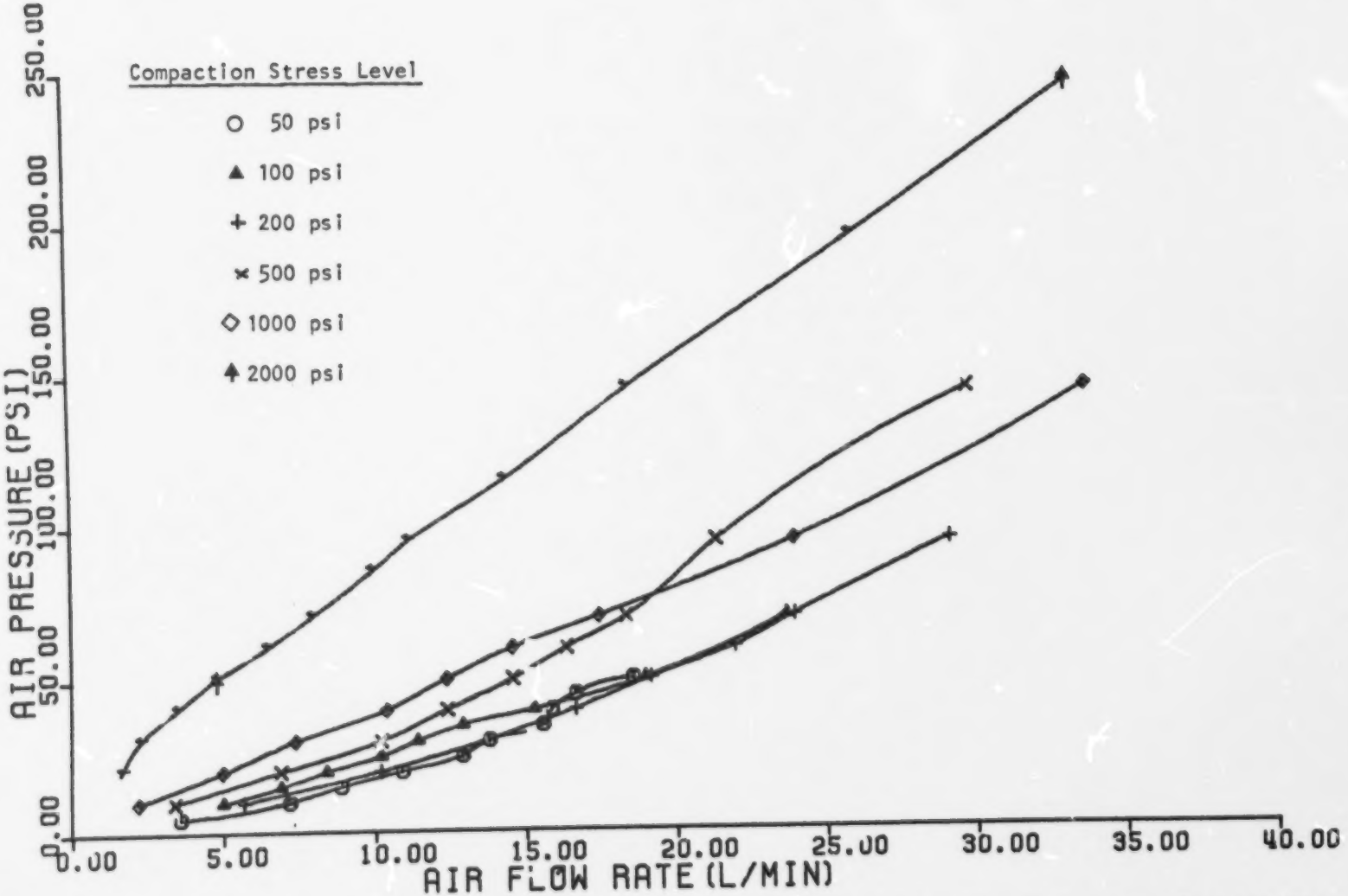

FIGURE NO. A-1: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, FINE INCREMENTAL (1ST SERIES) SAMPLES, TESTS #1 - 6 (M/C = 16%).

TABLE A-3: AIR PERMEABILITY DATA FOR TESTS #7 - 12

COAL DESCRIPTION: *Fine Large (as is) Incremental*

MOISTURE CONTENT:
Initial = 30%

WEIGHT OF SAMPLE = 11.45 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
13.5	0.0	0.0	0.0
12.63 - 12.69	50	10	17.0
		15	25.9
		20	32.0
12.56 - 12.63	100	10	17.8
		20	31.7
		25	36.9
11.88 - 12.06	200	10	17.0
		20	29.8
		25	3[illegible].2
10.88 - 11.0	500	20	20.4
		30	30.9
		40	38.0
10.06 - 10.56	1000	20	10.6
		30	15.9
		40	21.8
		60	31.4
9.31 - 9.88	2000	50	5.7
		100	14.0
		150	23.9
		200	32.3

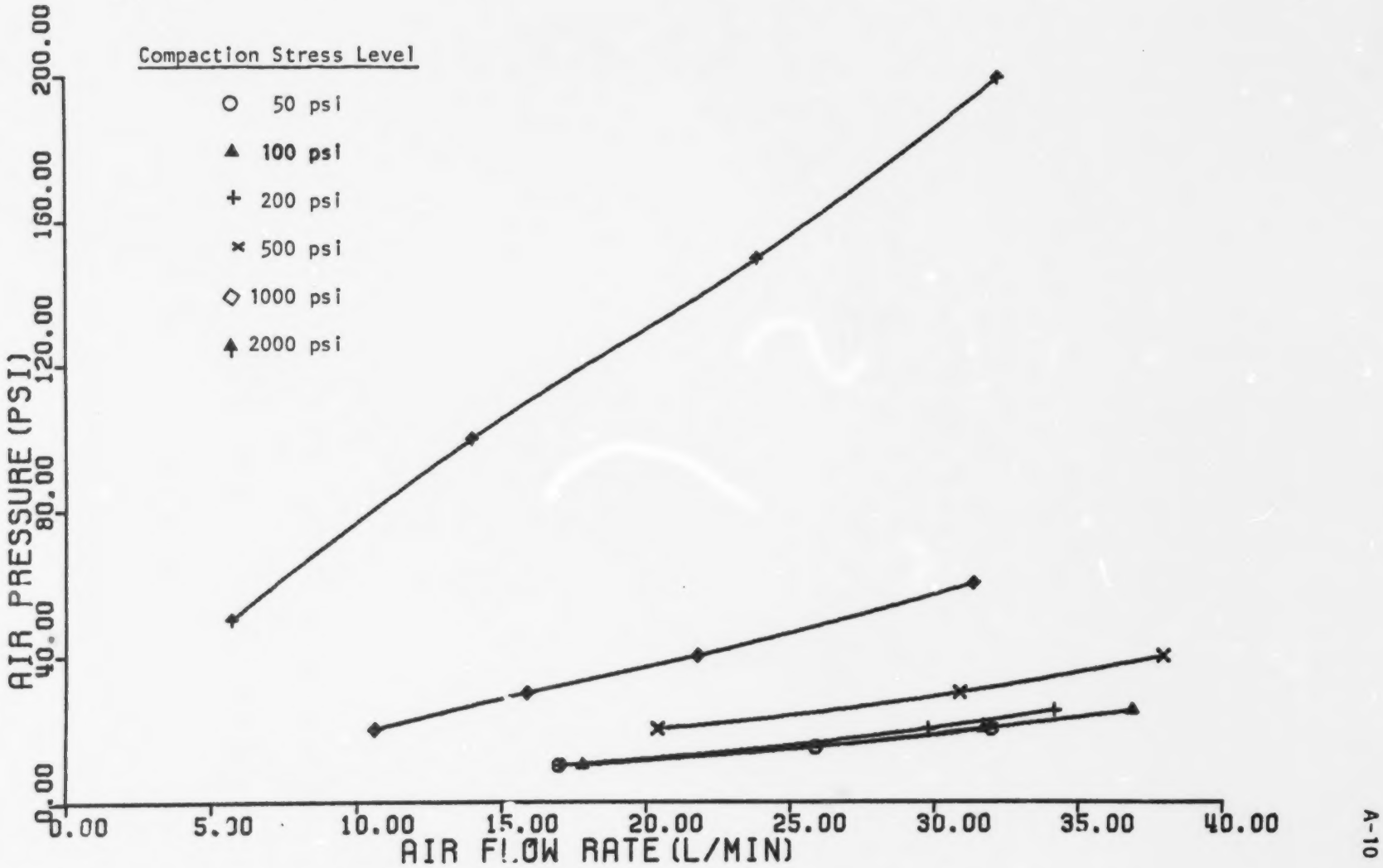

FIGURE NO. A-2: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, FINE INCREMENTAL (1ST SERIES) SAMPLES, TESTS #7 - 12 (M/C = 30%).

TABLE A-4: AIR PERMEABILITY DATA FOR TESTS #13 - 18

COAL DESCRIPTION: Fine Large (Wetted) Incremental

MOISTURE CONTENT:

Initial = 38.9%

WEIGHT OF SAMPLE = 10.53 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
13.5	0.0	0.0	0.0
10.69 - 10.75	50	10	17.0
		20	26.0
		30	34.6
9.94 - 10.13	100	15	19.2
		25	27.3
		40	38.3
9.31 - 9.63	200	20	22.3
		30	28.1
		40	34.6
8.35 -	500	30	15.4
		50	23.4
		75	32.3
	1000	*Sample saturated, water expelled*	
	2000	*Sample saturated, water expelled*	

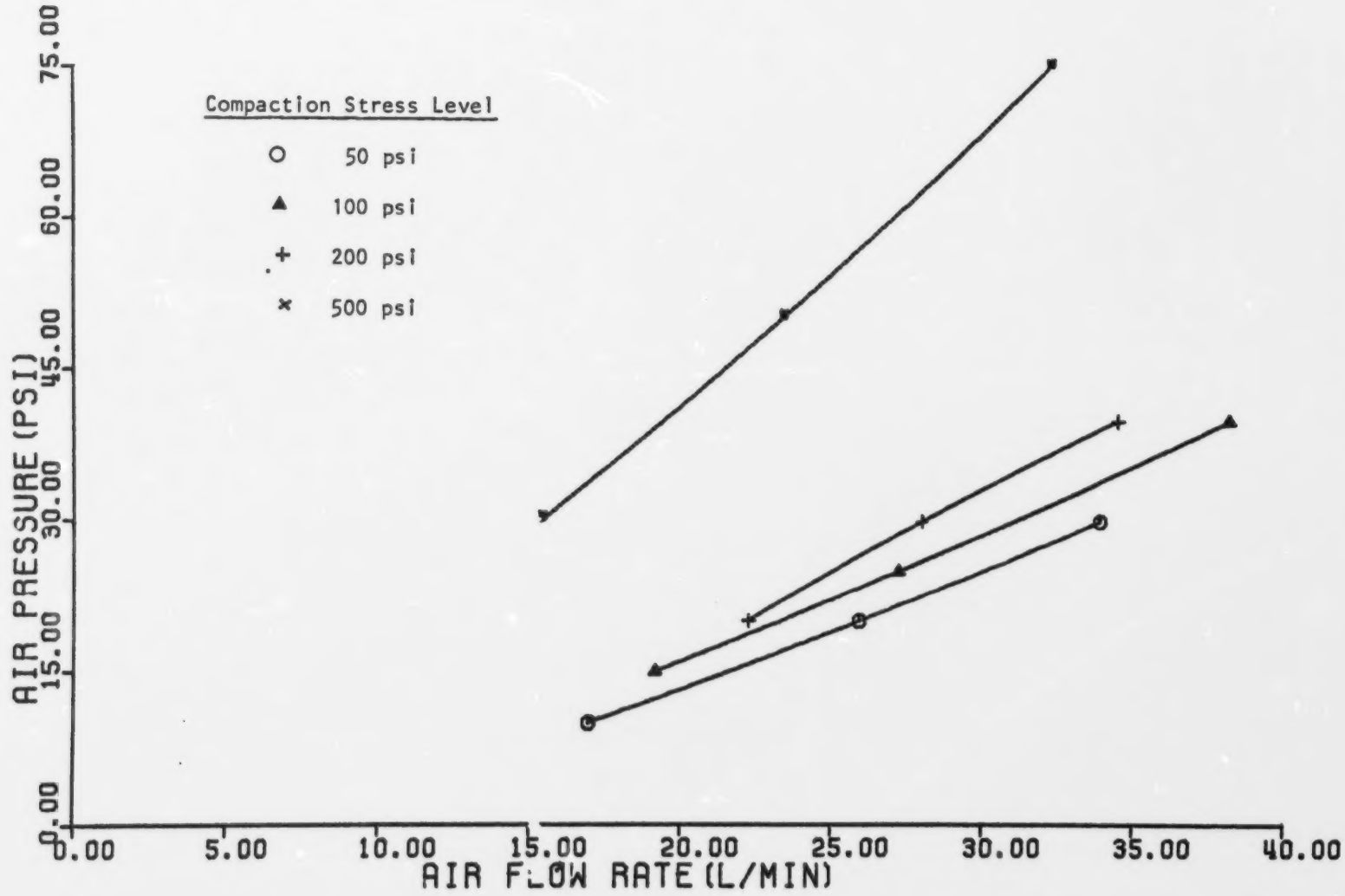

FIGURE NO. A-3: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, FINE INCREMENTAL (1ST SERIES) SAMPLES, TESTS #13 - 18 (M/C = 38.9%).

TABLE A-5: AIR PERMEABILITY DATA FOR TESTS #19 - 24

COAL DESCRIPTION: Large, Coarse, Incremental

MOISTURE CONTENT:

Initial = 11.5%

WEIGHT OF SAMPLE = 11.34 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.0	0.0	0.0	0.0
12.00 - 12.06	50	10	5.0
		20	10.0
		30	14.8
11.93 - 12.0	100	25	12.0
		50	20.6
		75	26.2
11.88 - 12.0	200	50	15.6
		100	32.6
11.31 - 11.63	500	50	17.5
		100	33.0
10.8 - 11.2	1000	50	13.7
		100	25.6
10.2 - 10.7	2000	50	9.4
		100	21.4

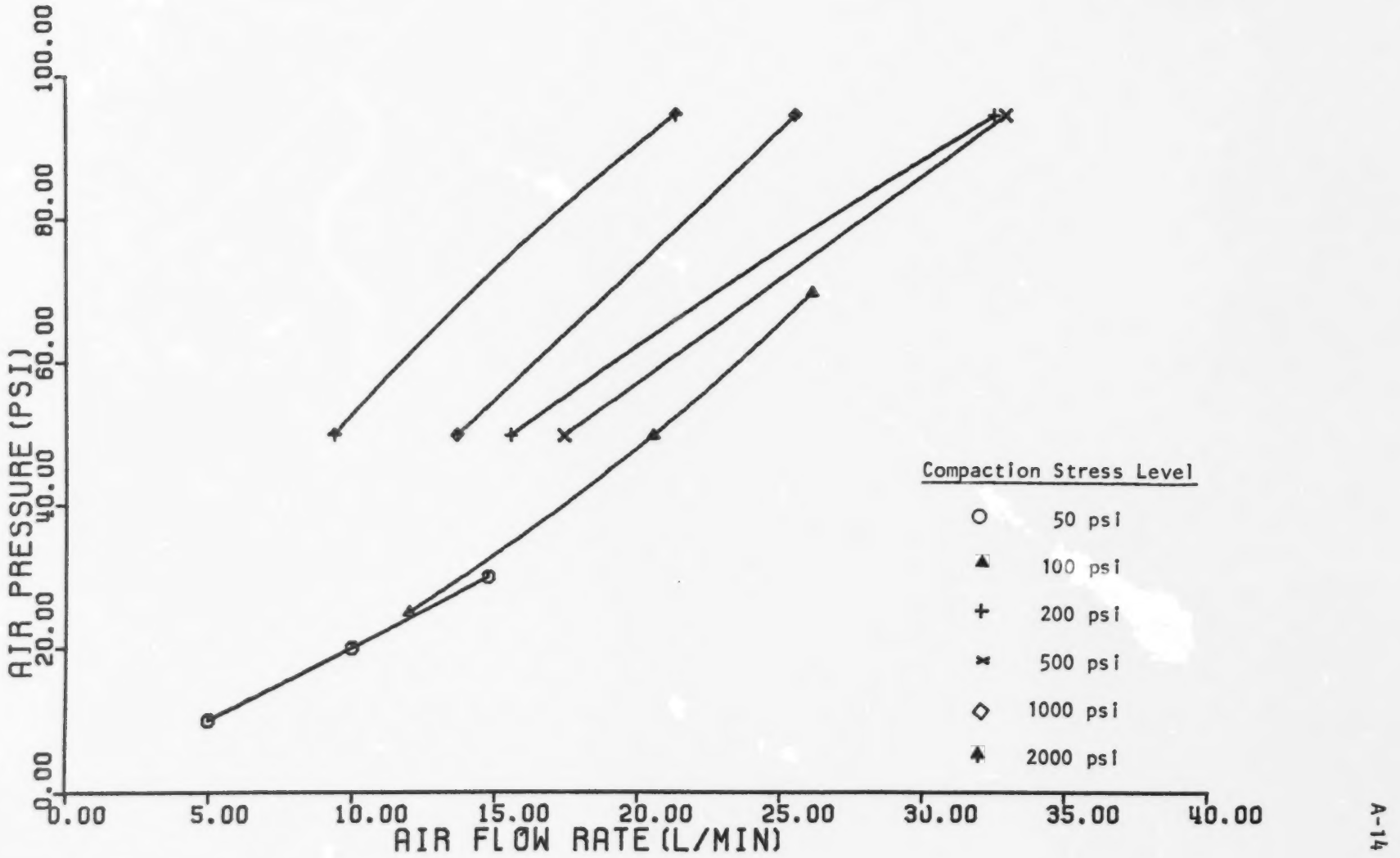

FIGURE NO. A-4: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, COARSE INCREMENTAL (1ST SERIES) SAMPLES, TESTS #19 - 24 (M/C = 11.5%).

TABLE A-6: AIR PERMEABILITY DATA FOR TESTS #25 - 30

COAL DESCRIPTION: Large, Coarse, Incremental

MOISTURE CONTENT:

Initial = 33.7%

WEIGHT OF SAMPLE = 11.24 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
13.5	0.0	0.0	0.0
13.0 - 13.06	50	10	17.5
		20	25.6
		30	34.2
12.3 - 12.4	100	25	28.0
		40	36.8
11.6 - 11.9	200	20	19.7
		30	28.4
		40	36.4
10.8 - 11.1	500	40	23.0
		50	29.4
		60	34.4
10.2 - 10.7	1000	50	11.4
		75	18.2
		100	26.6
		125	35.4
9.6 - 10.1	2000	50	2.4
		100	6.6
		200	19.0
		300	32.2

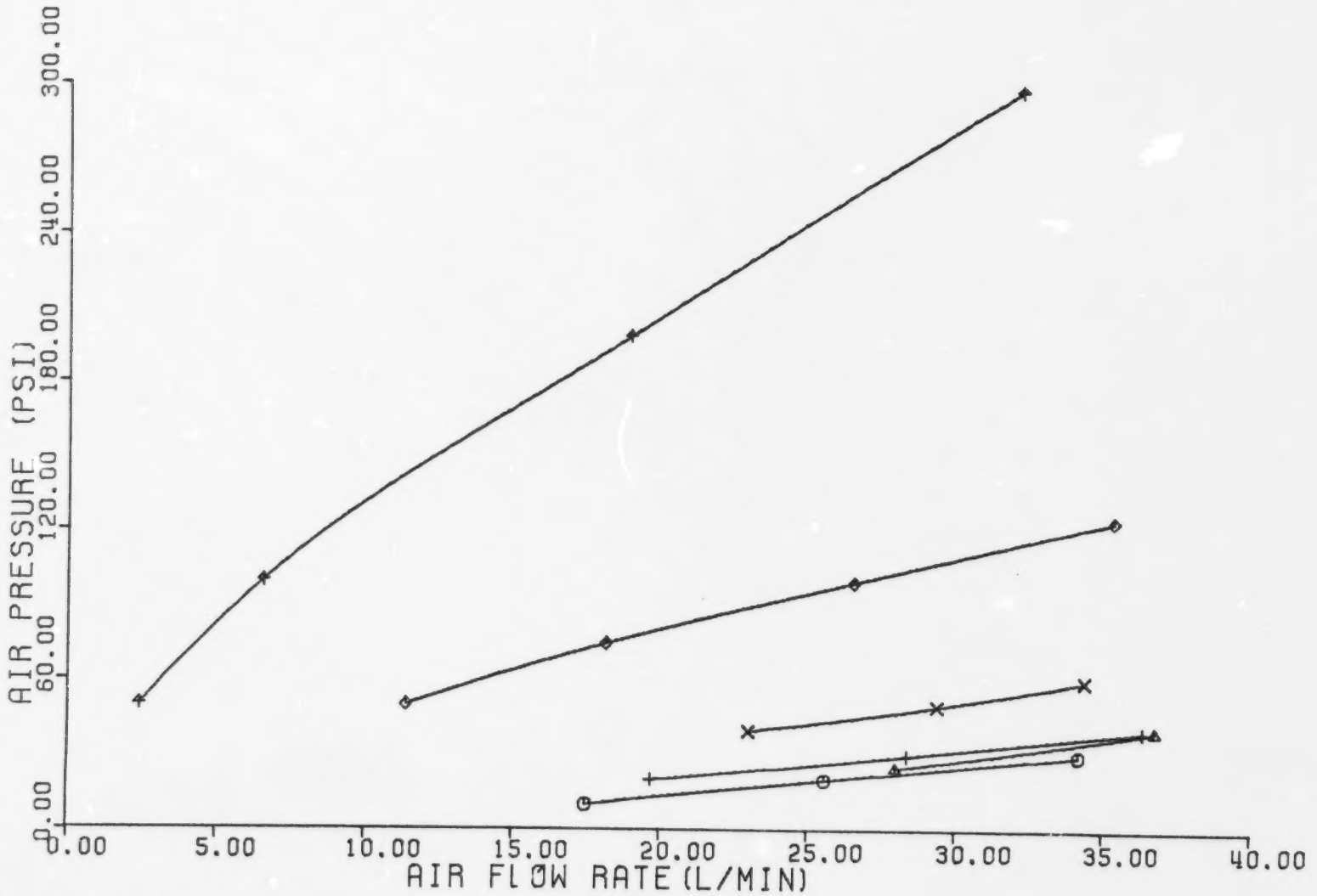

FIGURE NO. A-5: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, COARSE, INCREMENTAL (1ST SERIES) SAMPLES, TESTS #25 - 30 (M/C = 33.7%).

TABLE A-7: AIR PERMEABILITY DATA FOR TESTS #31 - 36

COAL DESCRIPTION: Large, Coarse, Incremental

MOISTURE CONTENT:
Initial = 41.7%

WEIGHT OF SAMPLE = 11.03 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.0	0.0	0.0	0.0
11.06 - 11.38	50	10	19.5
		20	30.9
10.7 - 11.0	100	25	34.2
10.1 - 10.3	200	20	26.7
		30	35.4
9.3 - 9.7	500	50	24 8
		75	37.8
8.8 - 9.3	1000	50	6.9
		100	13.6
		200	30.6
		250	37.4
8.2 - 9.1	2000	*Sample saturated, water expelled*	

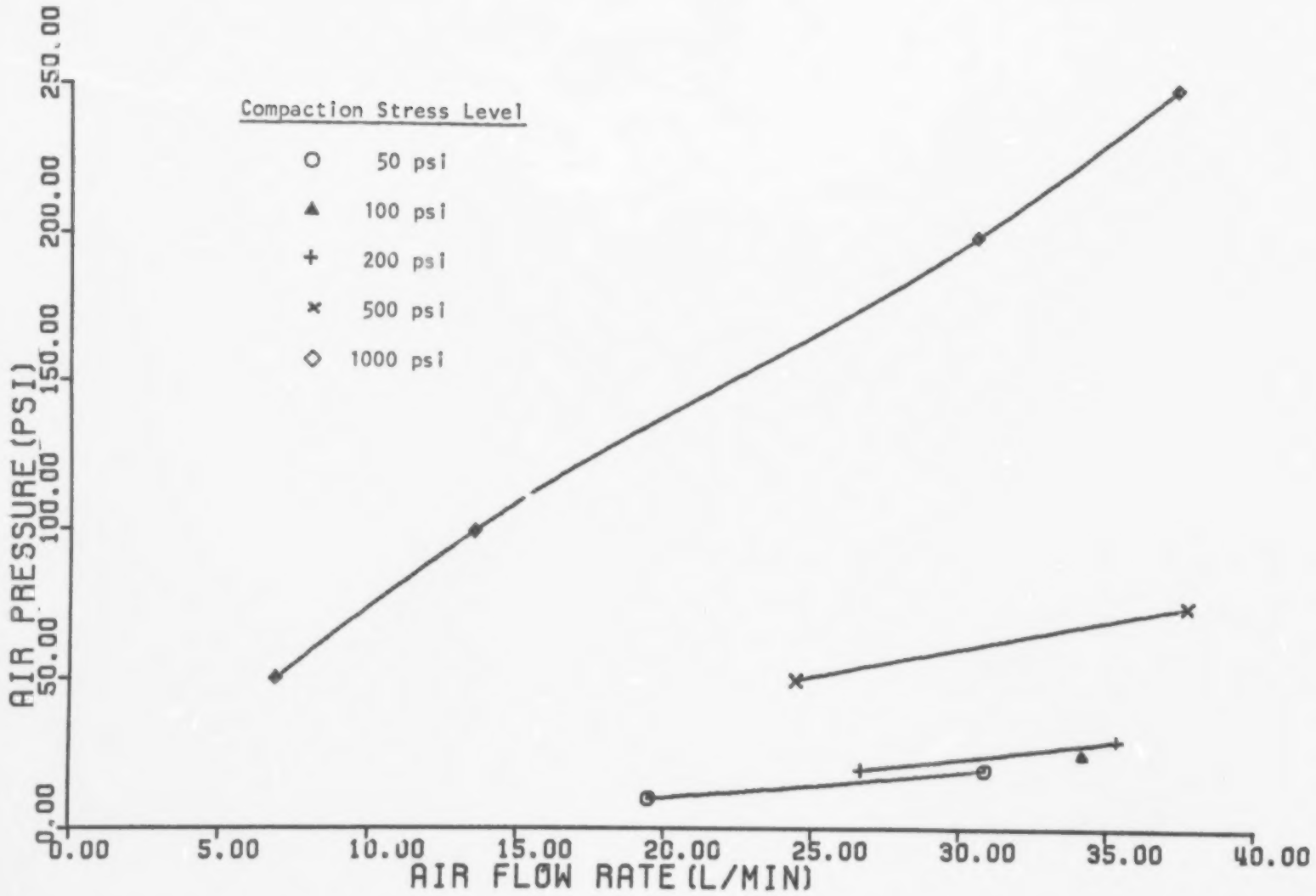

FIGURE NO. A-6: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, COARSE INCREMENTAL (1ST SERIES) SAMPLES, TESTS #31 - 36 (M/C = 41.7%).

TABLE A-8: AIR PERMEABILITY DATA FOR TESTS #37 - 42

COAL DESCRIPTION: Fine, Small (air dried) Incremental

MOISTURE CONTENT:

Initial = 15%

WEIGHT OF SAMPLE = 6.78 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
7.75	50	10	13.5
		15	18.6
		20	24.8
		25	30.6
		30	35.1
7.44	100	10	15.4
		15	22.0
		20	26.7
		25	31.2
		30	35.8
7.0 - 7.13	200	10	17.0
		15	23.4
		20	29.0
		25	33.1
		20	37.4
6.44 - 6.56	500	10	14.0
		15	19.5
		20	24.8
		25	28.6
		30	30.9
		35	34.8

Continued . . . . . .

Air Permeability Data for Test #37 to 42 continued

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
6.06 - 6.19	1000	10	8.9
		15	12.0
		20	14.6
		25	18.6
		30	21.4
		35	24.5
		40	27.3
5.63 - 5.88	2000	10	3.8
		15	6.1
		20	7.9
		25	9.6
		30	11.2
		35	12.7
		40	14.0
		45	16.4
		50	18.1
		55	19.5
		60	21.1
		70	24.2
		95	32.6

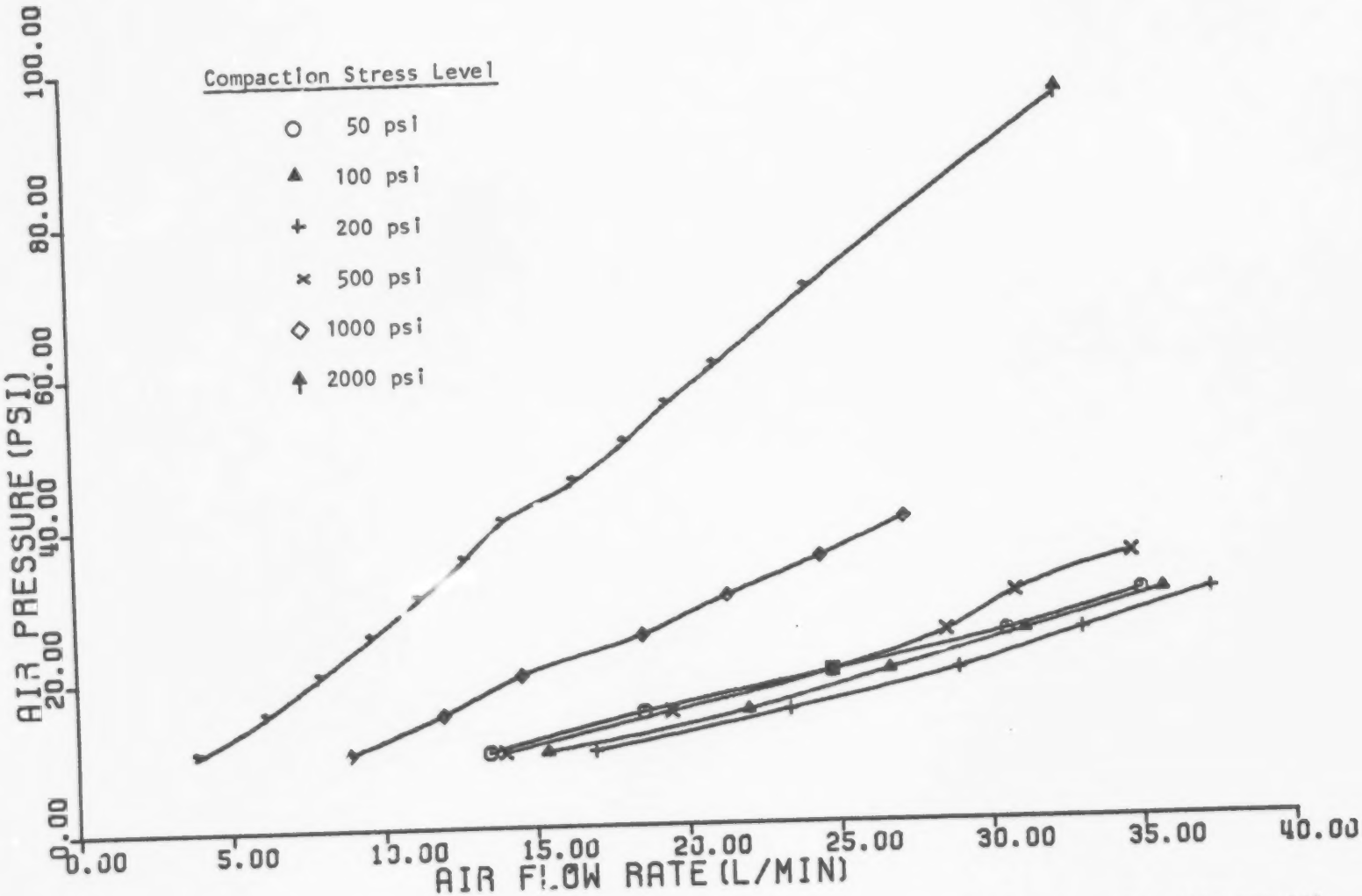

FIGURE NO. A-7: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR SMALL, FINE INCREMENTAL (1ST SERIES) SAMPLES, TESTS #37 - 42 (M/C = 15%).

TABLE A-9: AIR PERMEABILITY DATA FOR TESTS #43 - 48

COAL DESCRIPTION: Small, Fine, Incremental

MOISTURE CONTENT:

Initial = 31.4%

WEIGHT OF SAMPLE = 6.78 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
7.31	50	5	9.2
		10	14.0
		15	18.1
		20	21.1
		25	25.6
		30	28.4
		35	31.2
		40	34.6
7.0 - 7.13	100	10	11.9
		15	15.9
		20	20.1
		25	24.5
		30	27.6
		35	30.7
		40	33.4
6.56 - 6.75	200	10	9.9
		15	13.8
		20	17.8
		25	21.4
		30	24.5
		35	27.3
		40	30.1
		45	33.1
		50	35.8

Continued . . . . . .

Air Permeability Data for Tests #43 - 48 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
6.00 - 6.19	500	10	5.9
		15	9.4
		20	12.1
		25	14.8
		30	17.0
		35	19.8
		40	22.6
		45	25.1
		50	28.6
		55	30.9
		60	33.7
5.44 - 5.75	1000	10	2.4
		15	3.8
		20	5.7
		25	7.4
		30	9.2
		35	10.9
		40	12.7
		45	14.6
		50	16.4
		60	19.8
		70	22.0
		80	27.8
		90	32.6
		100	36.9

Continued . . . . . .

Air Permeability Data for Tests #43 - 48 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
4.88 - 5.38	2000	10	0.6
		15	1.0
		20	1.4
		30	2.2
		40	3.4
		50	4.5
		60	5.9
		70	7.2
		80	8.2
		90	9.4
		100	11.1
		120	14.3
		150	19.5
		190	25.1

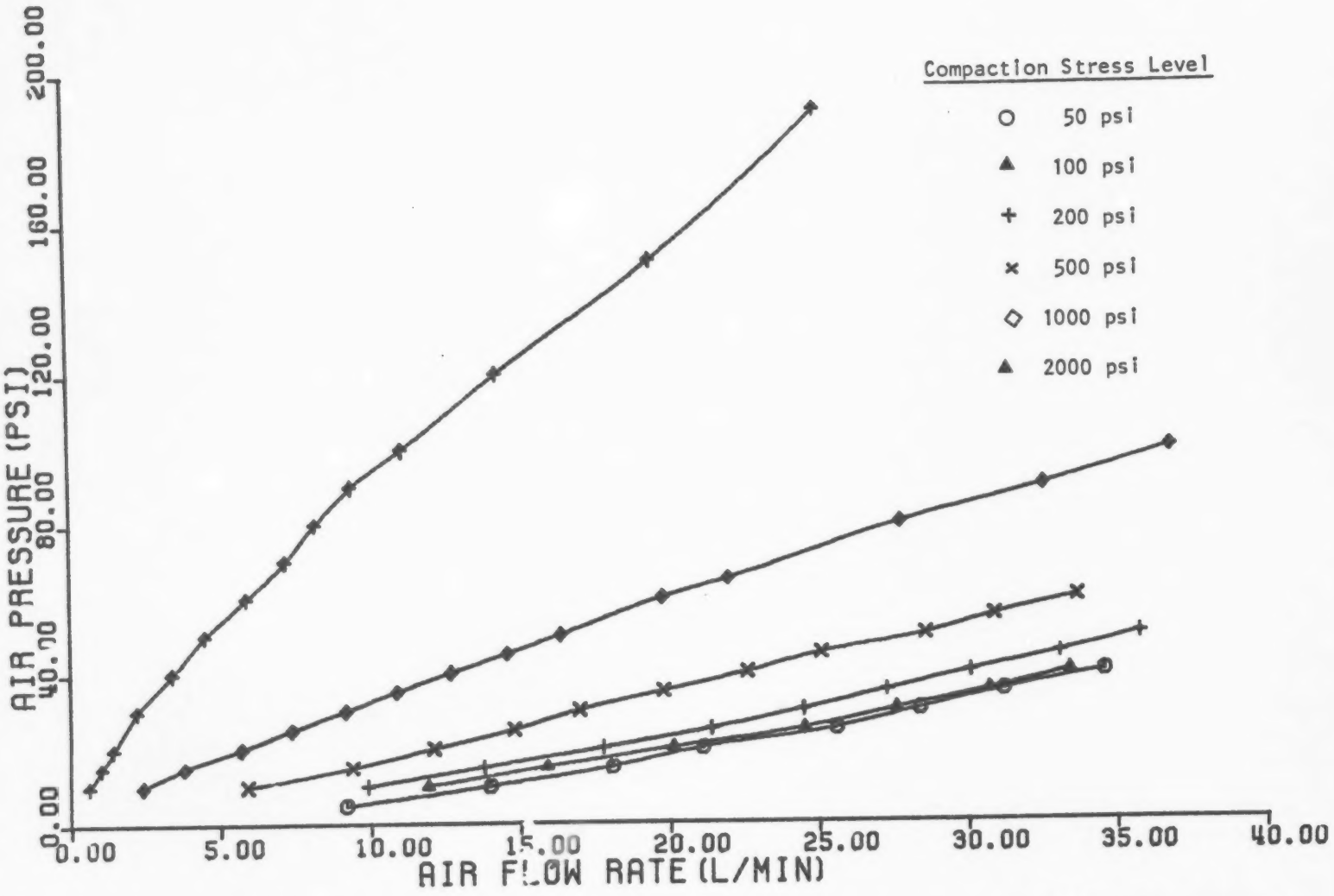

FIGURE NO. A-8: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR SMALL, FINE INCREMENTAL (1ST SERIES) SAMPLES, TESTS #43 - 48 (M/C = 31.4%).

TABLE A-10: AIR PERMEABILITY DATA FOR TESTS #49 - 54

COAL DESCRIPTION: Fine, Small (Wetted) Incremental

MOISTURE CONTENT:

Initial = 41.1%

WEIGHT OF SAMPLE = 6.16 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.5	0.0	0.0	0.0
6.75	50	10	12.1
		15	15.1
		20	17.3
		25	21.2
		30	23.7
		35	25.9
		40	29.8
6.25	100	10	10.4
		15	13.8
		20	16.7
		25	20.4
		30	22.8
		35	24.5
		40	28.6
		45	31.7
		50	34.3

Continued . . . . . .

Air Permeability Data for Tests #49 - 54 continued . . .

HEIGHT OF SAMPLE	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
5.81	200	10	8.2
		15	11.7
		20	14.8
		25	18.0
		30	20.6
		35	23.1
		40	26.2
		45	29.8
		50	33.1
		55	36.3
	500	*Sample saturated, water expelled*	
	1000	*Sample saturated, water expelled*	
	2000	*Sample saturated, water expelled*	

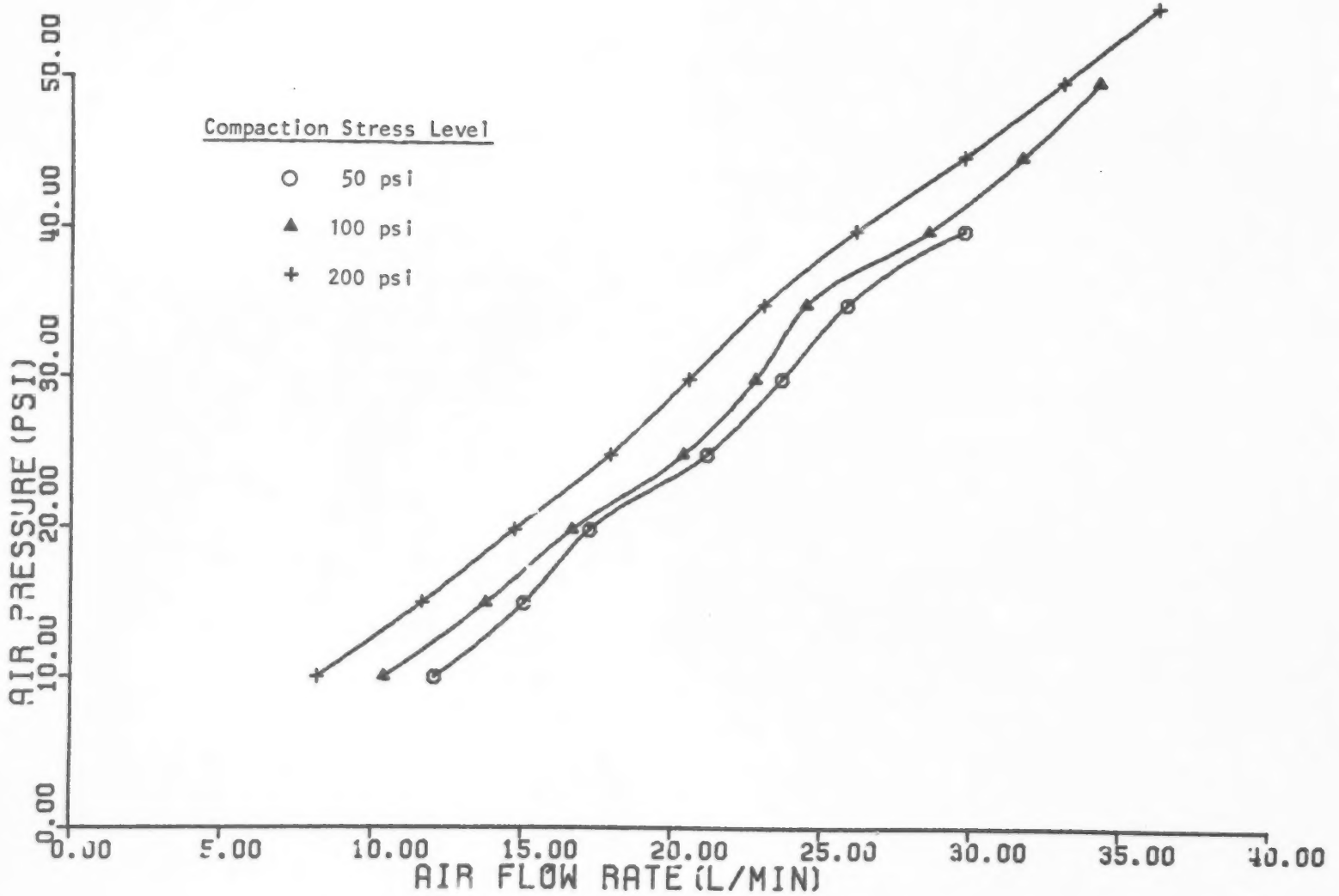

FIGURE NO. A-9: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR SMALL, FINE INCREMENTAL (1ST SERIES) SAMPLES, TESTS #49 - 54 (M/C = 41.1%).

TABLE A-11: AIR PERMEABILITY DATA FOR TESTS #55 - 60

COAL DESCRIPTION: Small, Fine (Air dried) Incremental

MOISTURE CONTENT:

Initial = 16.4%

WEIGHT OF SAMPLE = 5.99 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
7.31 - 7.38	50	10	4.0
		20	8.2
		30	12.0
		40	16.7
7.13 - 7.25	100	10	3.0
		20	6.6
		30	9.4
		40	12.0
		50	14.0
		60	15.9
		70	18.0
		80	19.8
7.0 - 6.94	200	10	3.4
		20	6.9
		30	9.4
		40	12.0
		50	13.8
		60	15.6
		70	17.2
		80	18.6
		90	20.6
		100	22.0

Continued . . . . . .

AIR PERMEABILITY DATA FOR TESTS #55-60 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
6.31 - 6.50	500	10	2.2
		20	5.4
		30	7.9
		40	10.2
		50	11.4
		60	13.2
		70	13.8
		80	14.8
		90	16.1
		100	17.5
		110	19.0
		120	20.6
		130	22.0
		140	22.8
5.94 - 6.19	1000	10	1.4
		20	3.2
		30	5.2
		40	7.2
		50	8.9
		60	10.6
		70	12.1
		80	14.0
		90	15.3
		100	16.7
		110	18.0
		120	19.2
		130	20.4
		140	21.4

Continued . . . . . .

AIR PERMEABILITY DATA FOR TESTS #55-60 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
5.56 = 5.88	2000	10	0.4
		20	1.2
		30	1.7
		40	2.8
		50	3.4
		60	4.3
		70	5.2
		80	6.2
		90	7.6
		100	8.4
		110	9.4
		120	10.4
		130	11.4

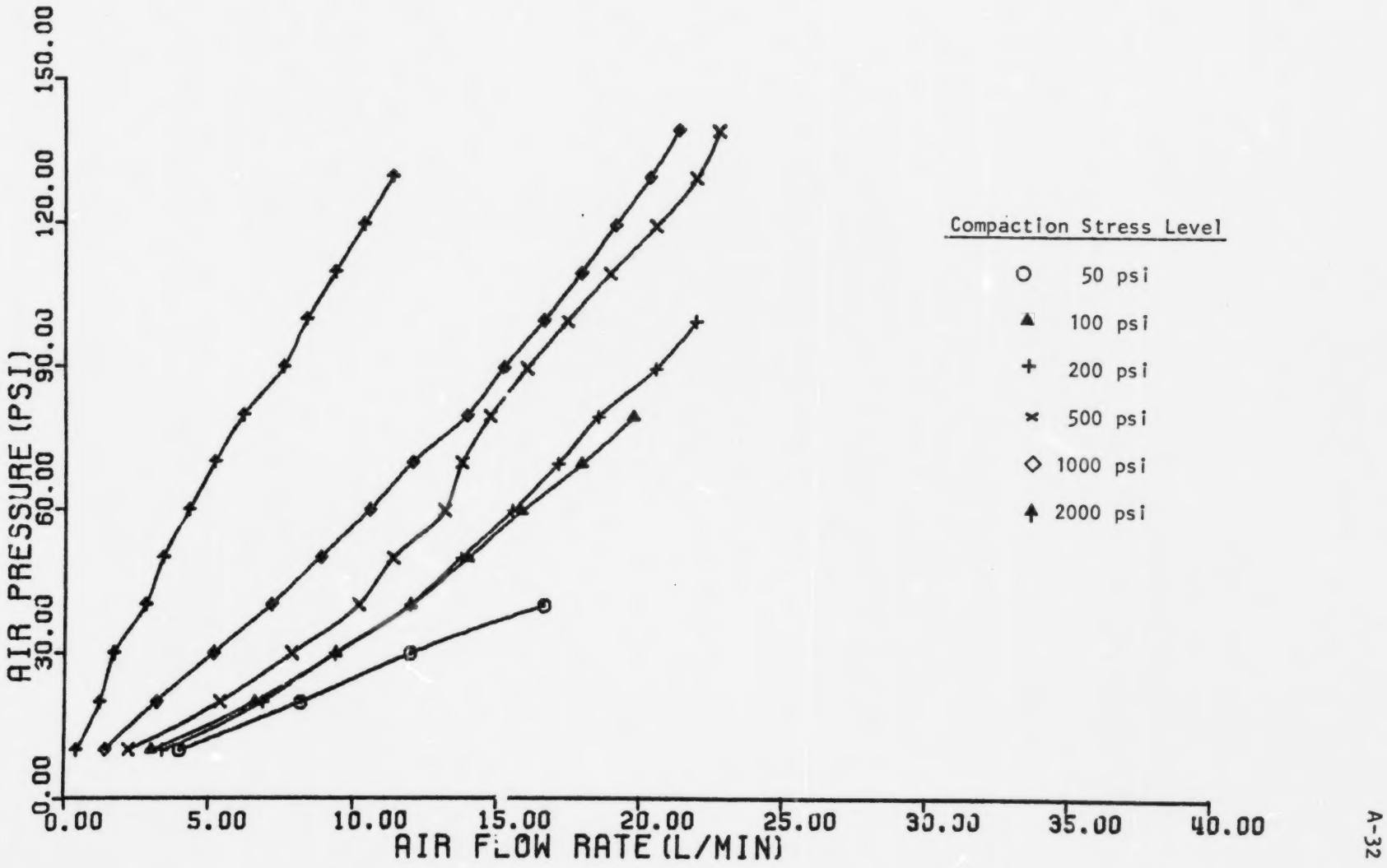

FIGURE NO. A-10: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, FINE INCREMENTAL (2ND SERIES) SAMPLES, TESTS #55 - 60 (M/C = 16.4%).

TABLE A-12: AIR PERMEABILITY DATA FOR TESTS #61 - 66

COAL DESCRIPTION: Small, Fine, Incremental - Series #2

MOISTURE CONTENT:

Initial = 29.6%

WEIGHT OF SAMPLE = 5.79 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
7.19	50	10	7.2
		20	12.1
		30	17.2
		40	22.0
7.31 - 7.38	100	10	6.1
		20	11.4
		30	15.6
		40	20.9
		50	28.1
		60	34.2
		70	37.8
7.13 - 7.25	200	10	6.1
		20	12.9
		30	17.5
		40	23.7
		50	28.1
		60	34.8
6.0 - 6.94	500	10	3.8
		20	9.4
		30	14.0
		40	19.0
		50	22.6
		60	26.7
		70	29.8
		80	33.1
		90	35.4

Continued . . . . . .

AIR PERMEABILITY DATA FOR TESTS #61-66 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
5.56 - 5.88	1000	10	1.4
		20	3.2
		30	5.4
		40	8.2
		50	10.6
		60	13.2
		70	15.6
		80	18.0
		90	20.6
		100	22.8
		110	25.6
		120	27.8
		130	30.7
		140	32.0
		150	33.7
5.13 - 5.5	2000	10	0.7
		20	1.0
		30	1.6
		40	1.8
		50	2.8
		60	3.0
		70	3.6
		80	4.5
		90	5.4
		100	6.1
		110	6.9
		120	7.6
		130	8.4
		140	9.1
		150	9.9

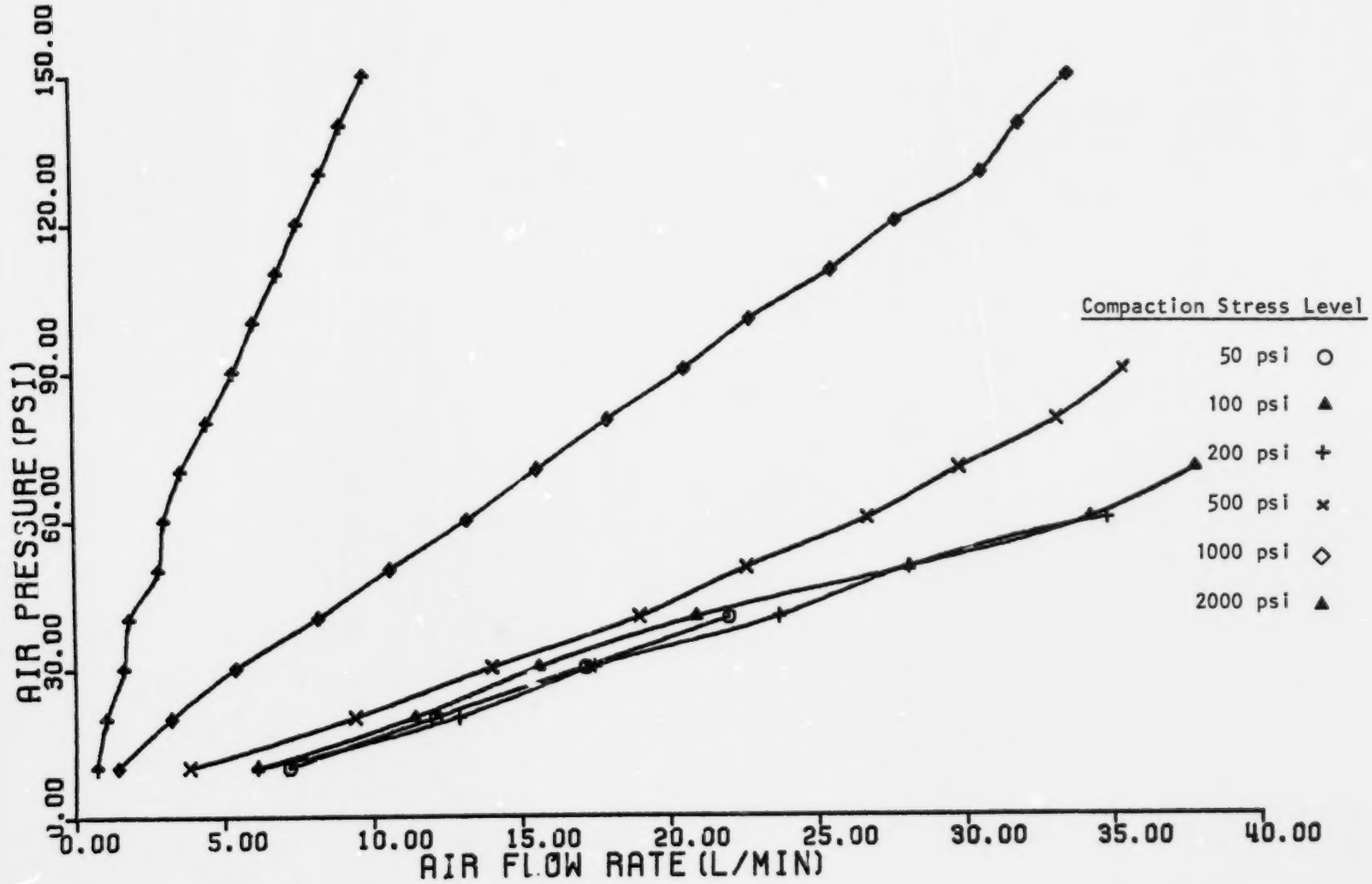

FIGURE NO. A-11: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, FINE INCREMENTAL (2ND SERIES) SAMPLES, TESTS #61 - 66 (M/C = 29.6%).

TABLE A-13: AIR PERMEABILITY DATA FOR TESTS #67 - 72

COAL DESCRIPTION: Small, Fine, Incremental

MOISTURE CONTENT:

Initial = 44.3%

WEIGHT OF SAMPLE = 5.33 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
6.13 - 6.19	50	10	3.4
		20	7.4
		30	9.9
		40	12.4
5.69 - 6.0	100	10	3.4
		20	6.4
		30	8.2
		40	10.4
		50	12.1
		60	14.6
		70	17.0
		80	18.4
5.31 - 5.78	200	10	2.2
		20	5.0
		30	7.4
		40	9.4
		50	11.7
		60	13.8
		70	15.9
		80	17.5
		90	19.2
	500	*Sample saturated, water expelled*	
	1000	*Sample saturated, water expelled*	
	2000	*Sample saturated, water expelled*	

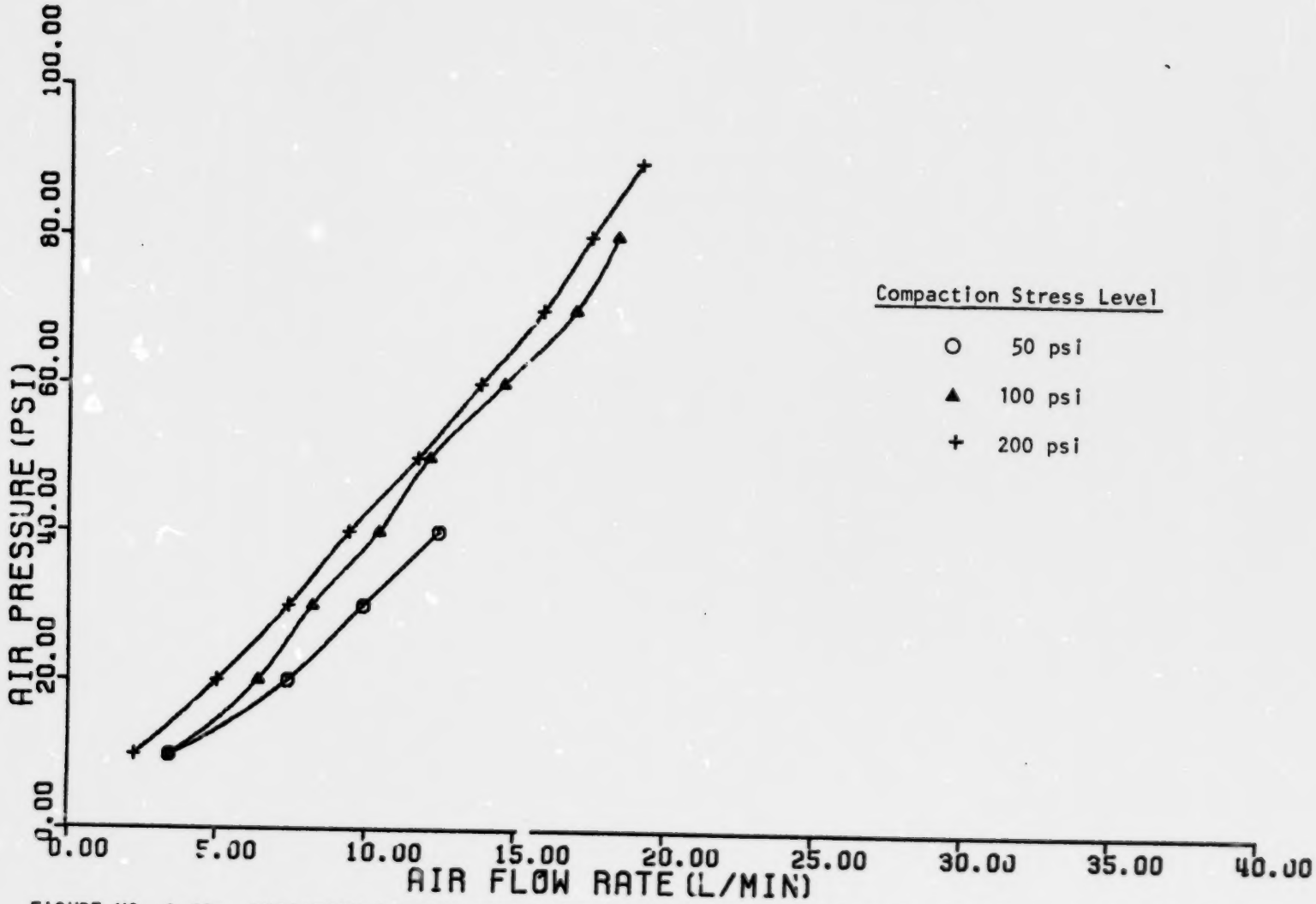

FIGURE NO. A-12: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, FINE INCREMENTAL (2ND SERIES) SAMPLES, TESTS #67 - 72 (M/C = 44.3%).

TABLE A-14: AIR PERMEABILITY DATA FOR TESTS #73 - 78

COAL DESCRIPTION: Small, Coarse, Incremental

MOISTURE CONTENT:

Initial = 19.3%

WEIGHT OF SAMPLE = 6.92 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.5	0.0	0.0	0.0
7.69	50	10	13.5
		15	19.8
		20	25.6
		25	30.3
		30	35.1
7.31 - 7.38	100	10	11.7
		15	16.7
		20	21.4
		25	25.9
		30	30.9
		35	35.4
6.94 - 7.00	200	10	10.4
		15	14.3
		20	18.0
		25	22.0
		30	25.5
		35	30.1
		40	33.6
		45	36.9

Continued . . . . . .

AIR PERMEABILITY DATA FOR TESTS #73-78 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
6.25 - 6.5	500	10	3.8
		15	6.1
		20	8.9
		25	11.4
		30	14.0
		35	17.2
		40	19.2
		45	22.0
		50	24.2
		55	26.7
		60	29.0
		75	33.6
		90	N/A
		100	N/A
5.94 - 6.25	1000	10	1.6
		15	2.4
		20	3.6
		25	5.0
		30	6.1
		35	7.9
		40	9.1
		45	10.6
		50	12.5
		55	13.7
		60	15.2
		70	18.1
		85	22.5
		95	25.9
		115	31.8
		150	N/D

Continued . . . . . .

AIR PERMEABILITY DATA FOR TESTS #73-78 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/Min)
5.38 - 5.88	2000	10	0.4
		20	0.7
		30	1.2
		40	1.8
		50	2.6
		60	3.4
		70	4.3
		80	5.2
		90	6.4
		100	7.4
		110	8.4
		120	9.4
		130	10.6
		140	12.7
		150	13.8
		160	15.1
		170	16.7
		180	17.5
		190	N/D

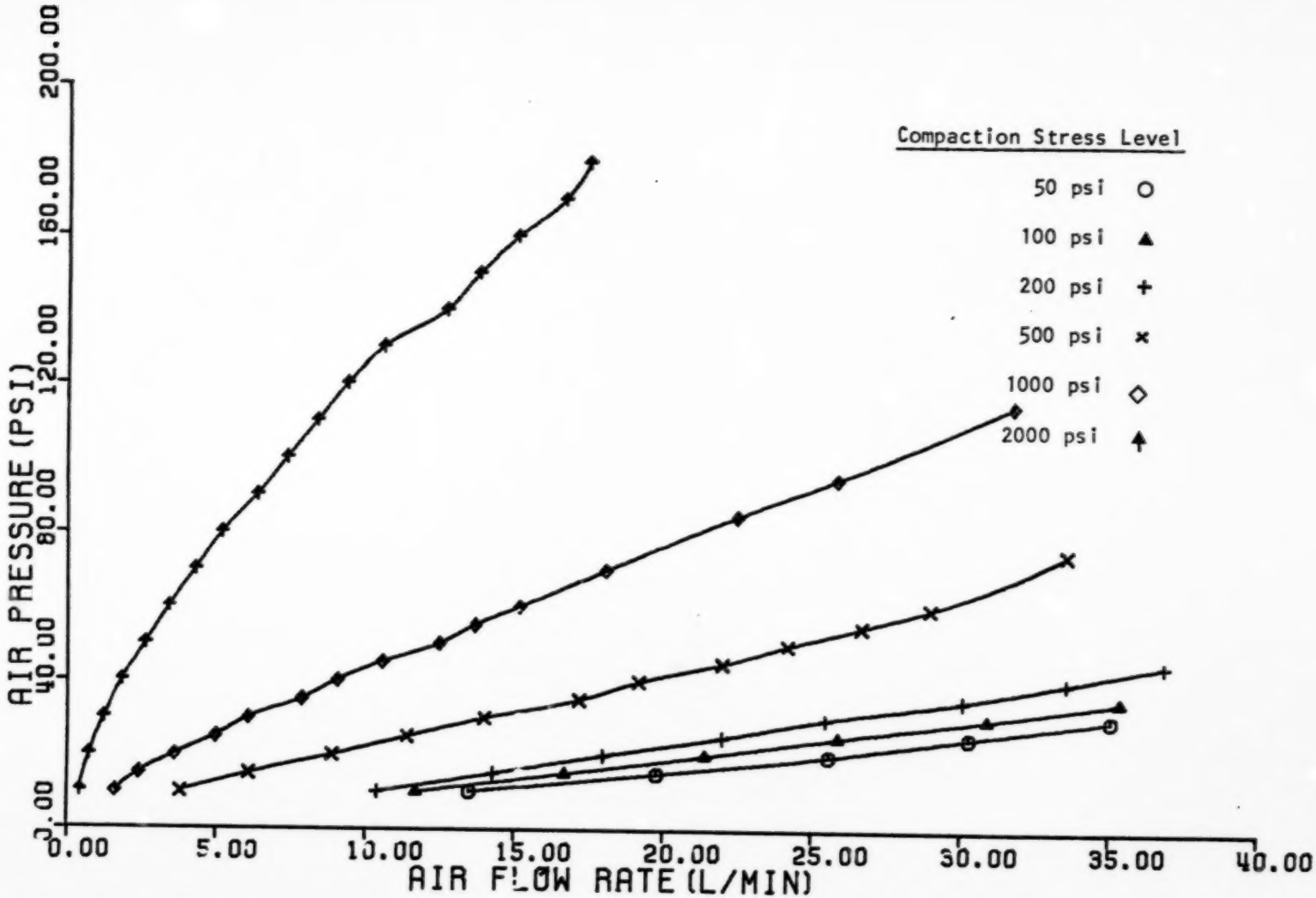

FIGURE NO. A-13: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, COARSE INCREMENTAL (2ND SERIES) SAMPLES, TESTS #73 - 78 (M/C = 19.3%).

TABLE A-15: AIR PERMEABILITY DATA FOR TESTS #79 - 84

COAL DESCRIPTION: Small, Coarse, Incremental

MOISTURE CONTENT:

Initial = 36.8%

WEIGHT OF SAMPLE = 6.39 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (Inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.5	0.0	0.0	0.0
6.75	50	10	17.8
		15	24.8
		20	30.1
		25	34.9
6.38	100	10	15.1
		15	23.4
		20	28.4
		25	33.4
6.25 - 6.13	200	10	14.3
		15	20.1
		20	25.9
		25	30.3
		30	34.3
5.5 - 5.75	500	10	8.4
		15	12.1
		20	15.6
		25	18.6
		30	22.8
		35	26.1
		40	28.7
		45	31.7
		50	34.0
		55	36.9

Continued . . . . . .

AIR PERMEABILITY DATA FOR TESTS #79-84 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
5.5 - 5.75	1000	10	1.2
		15	1.8
		20	2.6
		25	3.6
		30	4.5
		35	5.4
		40	6.4
		45	7.4
		50	8.2
		55	8.9
		60	10.0
		65	10.9
		75	12.4
		85	14.3
		95	15.9
		105	17.5
		115	19.2
		125	21.8
		135	23.7
		145	25.3
		155	27.0
		165	29.2
		175	31.2
		185	32.6
	2000	*Sample saturated, water expelled*	

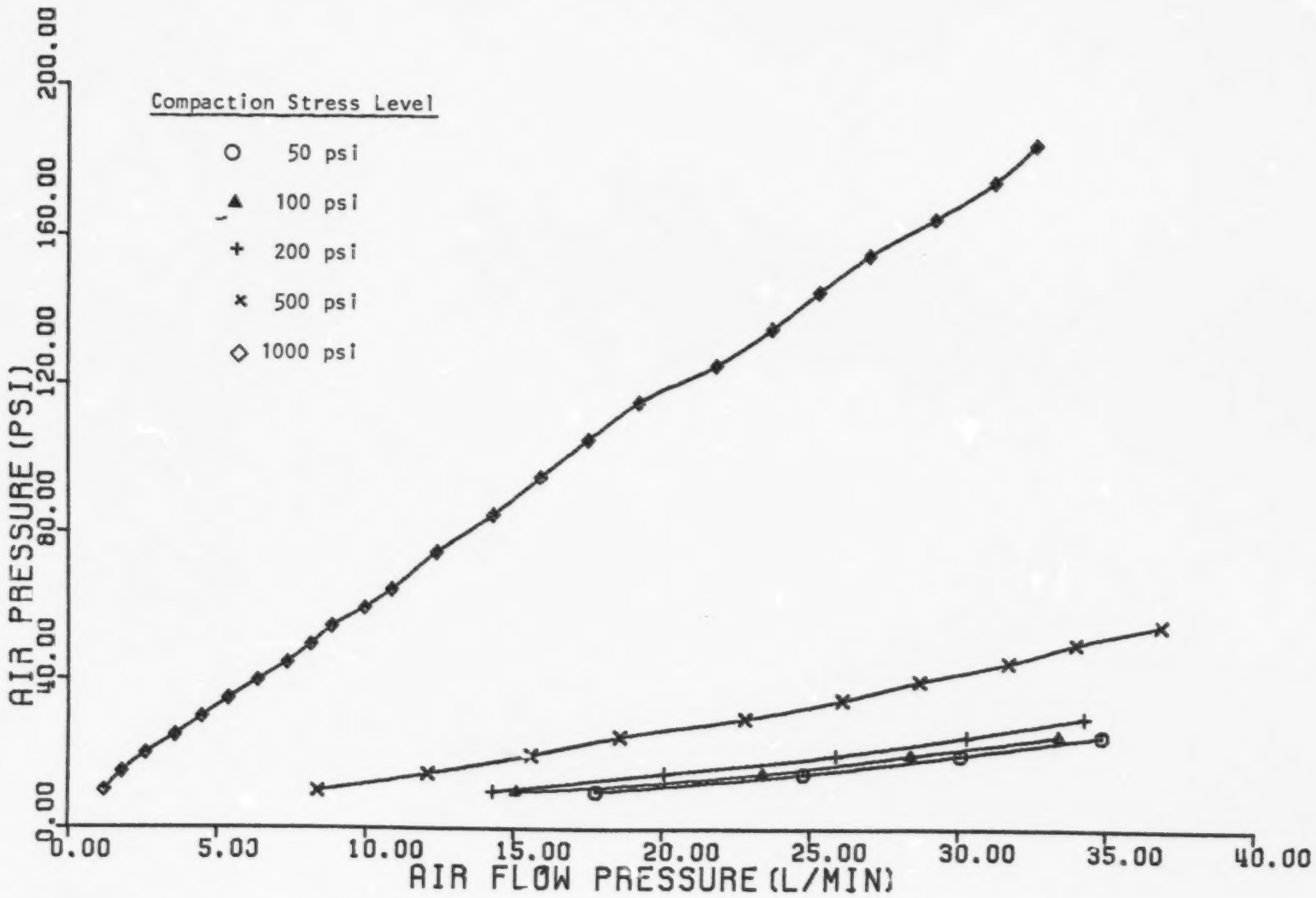

FIGURE NO. A-14: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, COARSE INCREMENTAL (2ND SERIES) SAMPLES, TESTS #79 - 84 (M/C = 36.8%).

TABLE A-16: AIR PERMEABILITY DATA FOR TESTS #85 - 90

COAL DESCRIPTION: Coarse, Small, Incremental

MOISTURE CONTENT:

Initial = 42.4%

WEIGHT OF SAMPLE = 7.2 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
6.31 - 6.44	50	10	17.0
		15	24.0
		20	29.8
		25	35.2
6.25 - 6.38	100	10	16.7
		15	23.7
		20	29.8
		25	34.6
6.06	200	10	14.8
		15	22.3
		20	27.6
		25	34.0
	500	*Sample saturated, water expelled*	
	1000	*Sample saturated, water expelled*	
	2000	*Sample saturated, water expelled*	

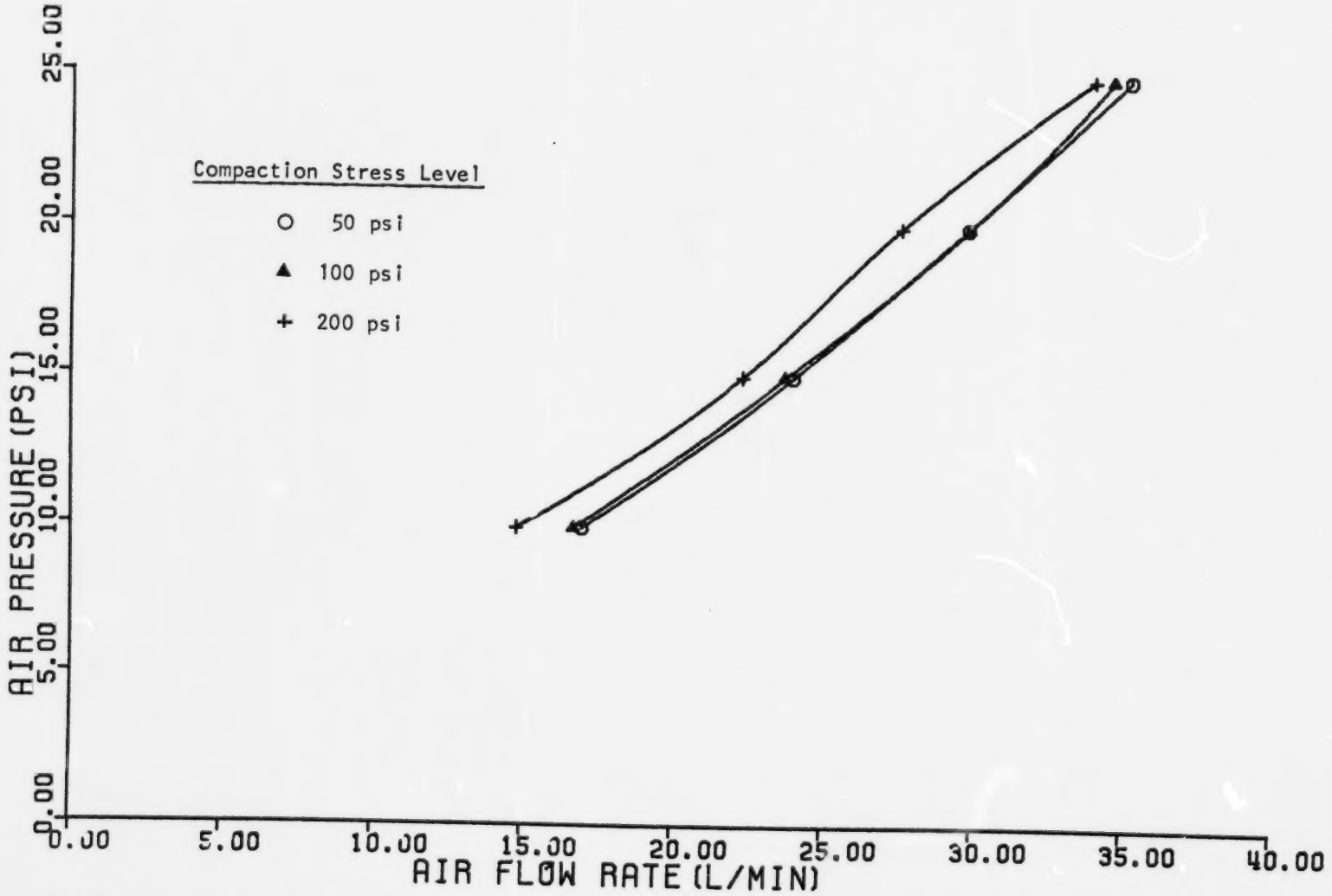

FIGURE NO. A-15: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, COARSE INCREMENTAL (2ND SERIES) SAMPLES, TESTS #85 - 90 (M/C = 42.4%).

TABLE A-17: AIR PERMEABILITY DATA FOR TESTS #91 - 96

COAL DESCRIPTION: Coarse, Small (Air Dried) Incremental

MOISTURE CONTENT:

Initial = 12.4%

WEIGHT OF SAMPLE = 5.63 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
7.31 - 7.44	50	10	9.4
		20	20.4
		30	28.4
		40	36.0
6.83 - 7.00	100	10	12.9
		20	23.1
		30	30.9
		40	38.2
6.5 - 6.75	200	10	12.0
		20	22.8
		30	30.9
		40	37.8
6.06 - 6.31	500	10	9.9
		20	17.8
		30	24.8
		40	31.4
	1000	*Sample Saturated, water expelled*	
	2000	*Sample Saturated, water expelled*	

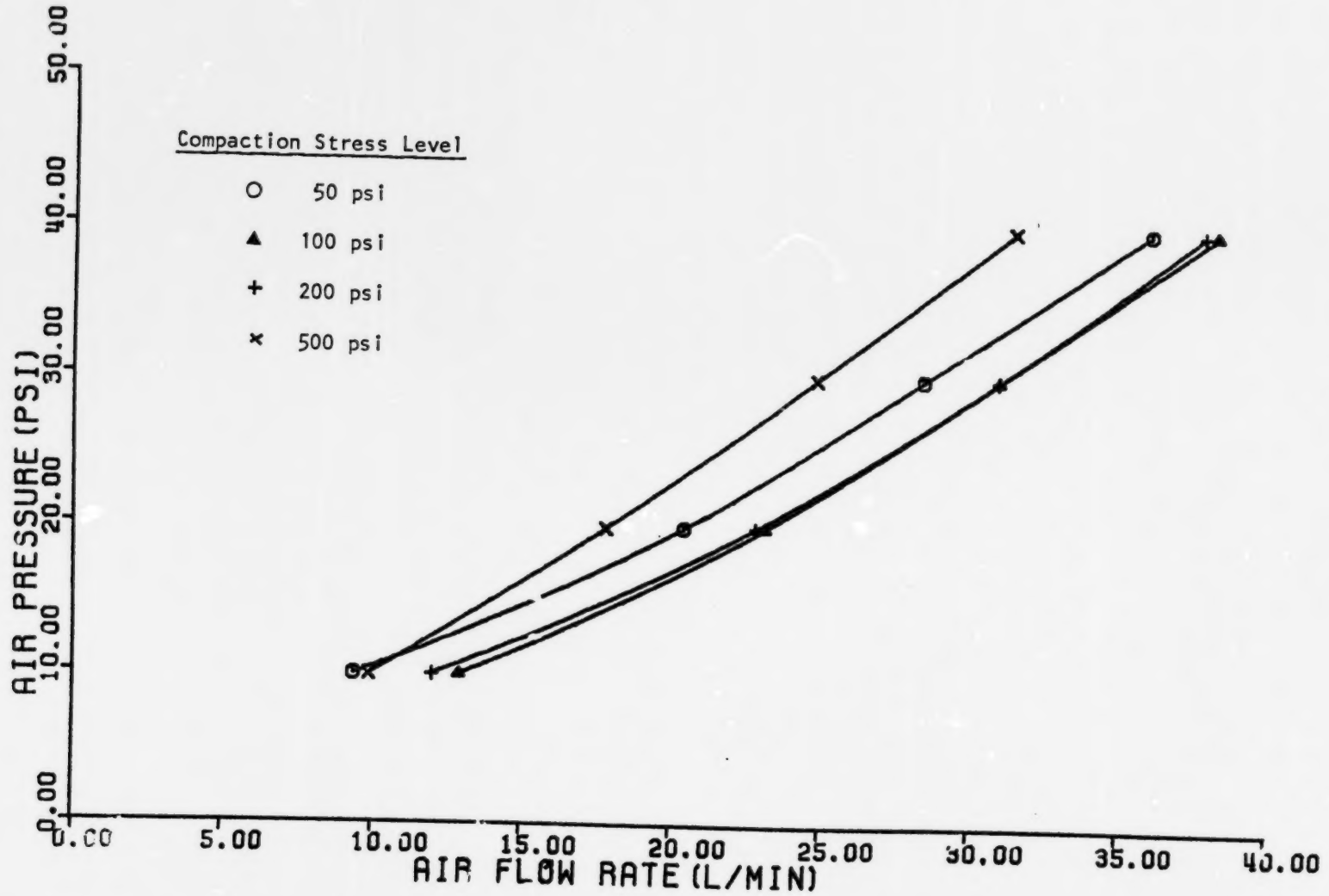

FIGURE NO. A-16: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, COARSE, INCREMENTAL (2ND SERIES) SAMPLES, TESTS #91 - 96 (M/C = 12.4%).

TABLE A-18: AIR PERMEABILITY DATA FOR TESTS #97 - 102

COAL DESCRIPTION: Small, Coarse (As is) Incremental

MOISTURE CONTENT:

Initial = 35.3%

WEIGHT OF SAMPLE = 6.037 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
6.31 - 6.38	50	10	7.6
		20	16.7
		30	25.9
6.13 - 6.19	100	10	6.9
		20	16.2
		30	24.2
		40	31.2
		50	37.1
5.88 - 5.94	200	10	3.6
		20	10.4
		30	15.9
		40	32.3
		50	26.4
		60	30.9
		70	36.3
5.38 - 5.69	500	10	0.9
		20	2.0
		30	3.4
		40	5.2
		50	7.2
		60	9.1
		70	11.1
		80	12.9

Continued. . . . . .

AIR PERMEABILITY DATA FOR TESTS #97 - 102 continued . . .

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
		90	16.2
		100	19.0
		110	21.4
		120	24.8
5.06 - 5.38	1000	50	0.3
		60	0.5
		70	0.6
		80	0.8
		90	1.0
		100	1.1
		110	1.2
		120	1.4
		130	1.6
		140	1.8
5.76 - 5.25	2000	Sample saturated. water expelled	

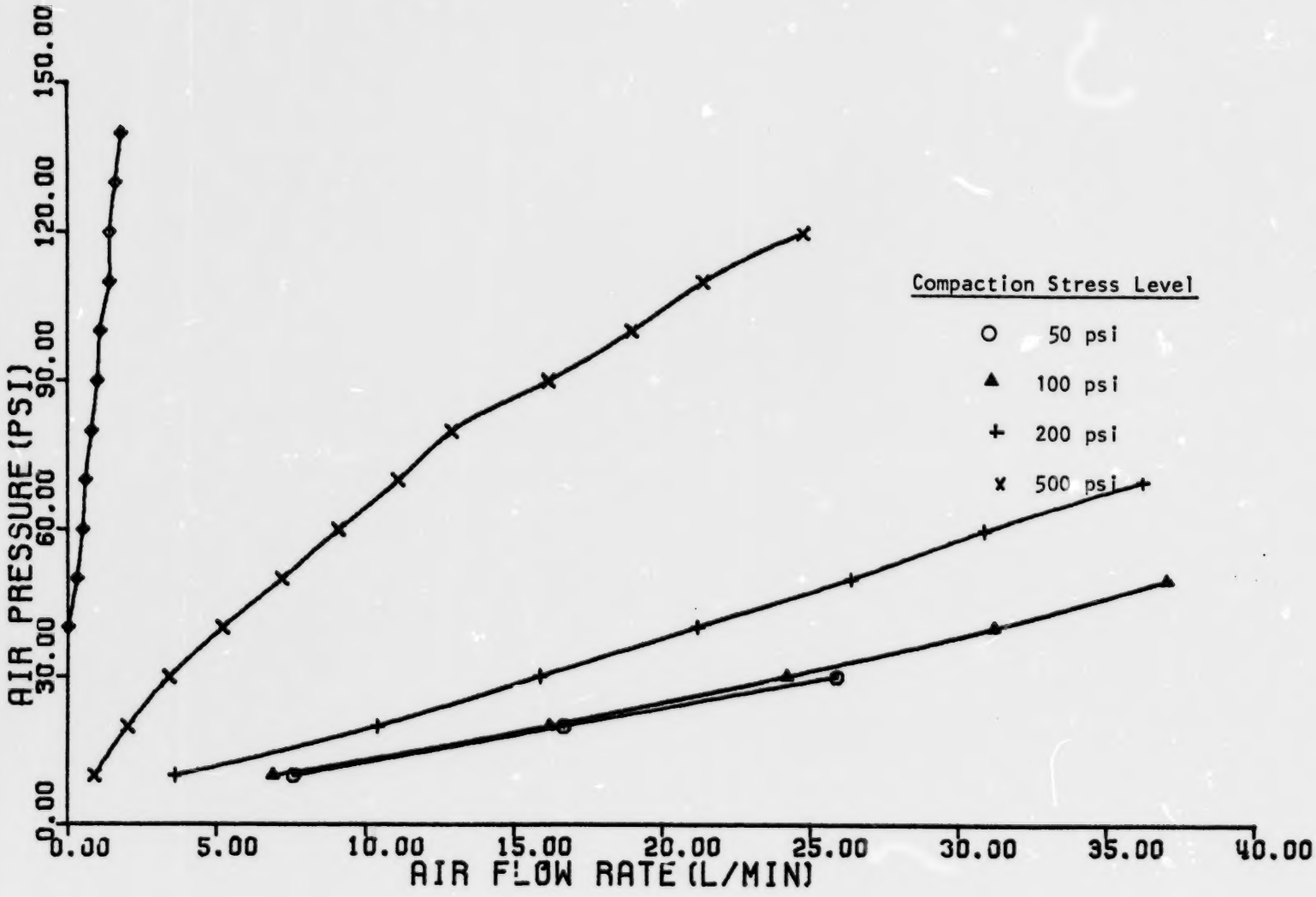

FIGURE NO. A-17: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, COARSE INCREMENTAL (2ND SERIES) SAMPLES, TESTS #97 - 102 (M/C = 35.3%).

TABLE A-19: AIR PERMEABILITY DATA FOR TESTS #103 - 108

COAL DESCRIPTION: Small, Coarse, Incremental

MOISTURE CONTENT:

Initial = 41.3%

WEIGHT OF SAMPLE = 6.26 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
6.5	50	10	7.2
		20	8.4
		30	12.4
		40	16.2
6.06 - 6.19	100	10	4.7
		20	9.9
		30	14.6
		40	19.0
		50	22.0
		60	24.2
		70	27.3
		80	29.8
5.75 - 5.94	200	10	3.4
		20	7.9
		30	12.0
		40	15.1
		50	18.6
		60	23.7
		70	27.5
		80	29.8
5.31 - 5.56	500	*Sample saturated, water expelled*	
	1000	*Sample saturated, water expelled*	
	2000	*Sample saturated, water expelled*	

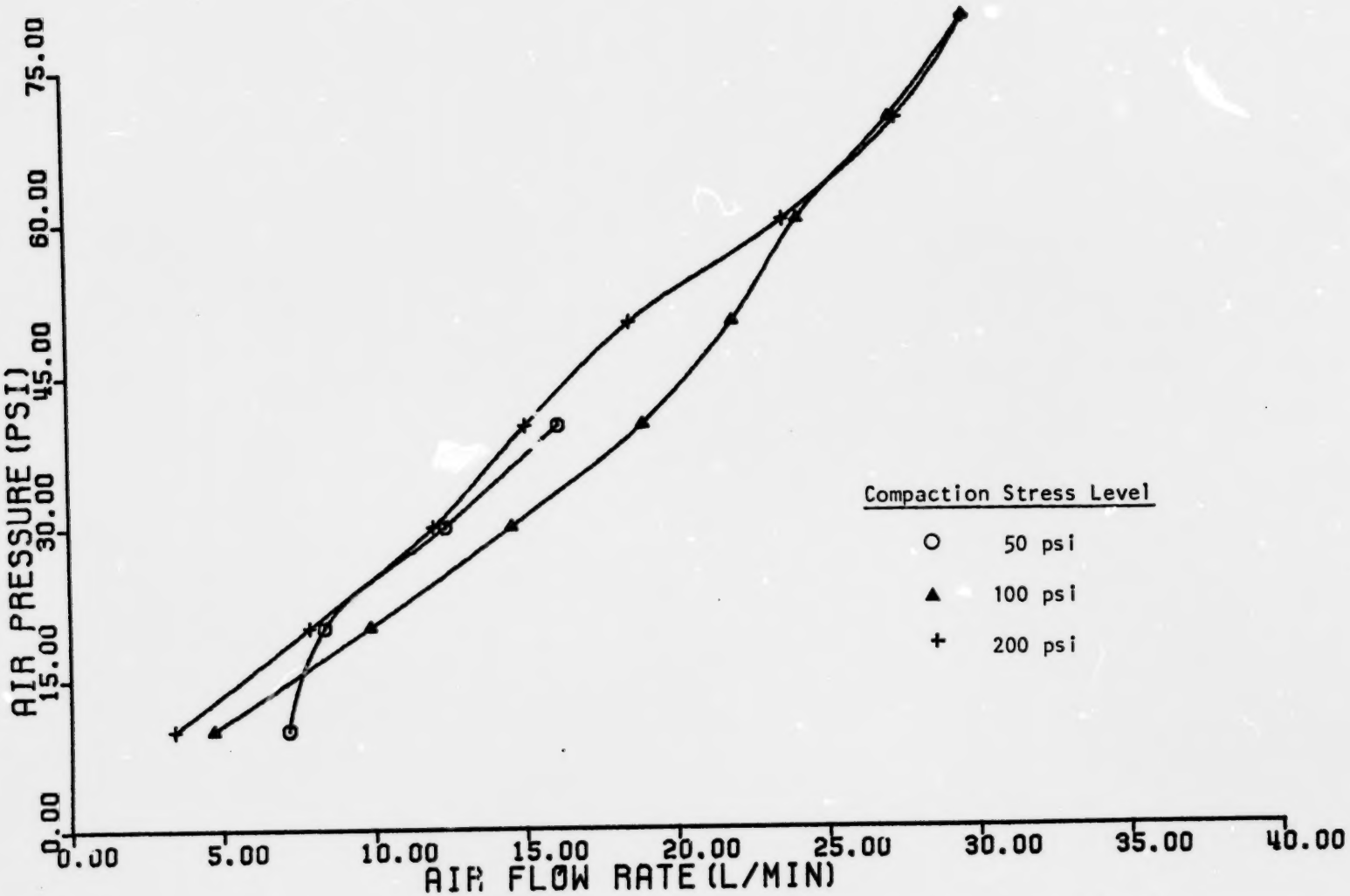

FIGURE NO. A-18: VARIATION IN FLOW RATE WITH APPLIED AIR PRESSURE LEVEL FOR SMALL, COARSE INCREMENTAL (2ND SERIES) SAMPLES, TESTS103 - 108 (M/C = 41.3%).

TABLE A-20: AIR PERMEABILITY DATA FOR TEST # 109

COAL DESCRIPTION: Coarse, Large (Air Dried) Single

MOISTURE CONTENT:

Initial = 14.0%

WEIGHT OF SAMPLE = 10.96 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
12.94	100	10	2.4
		20	6.1
		30	8.9
		40	10.4
		50	12.2
		60	14.6
		65	15.9
		75	19.2
		85	22.3

TABLE A-21: AIR PERMEABILITY DATA FOR TEST #110

COAL DESCRIPTION: Coarse, Large (Air Dried) Single

MOISTURE CONTENT:

Initial = 14.5%

WEIGHT OF SAMPLE = 11.19 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
10.63 - 11.13	1000	10	4.7
		20	8.9
		30	12.7
		40	15.1
		50	18.4
		60	21.7
		65	23.0
		75	25.6
		85	28.0
		95	30.3
		105	32.3
		115	36.0

TABLE A-22: AIR PERMEABILITY DATA FOR TEST # 111

COAL DESCRIPTION: Coarse, Large (Air Dried) Single

MOISTURE CONTENT:

Initial = 13.6%

WEIGHT OF SAMPLE = 11.27 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
9.83 - 10.38	2000	10	0.75
		20	1.75
		30	2.8
		40	4.0
		50	5.5
		60	6.1
		65	7.4
		75	8.9
		85	10.2
		95	11.4
		105	12.7
		115	13.8
		125	14.8
		135	16.1
		145	17.8

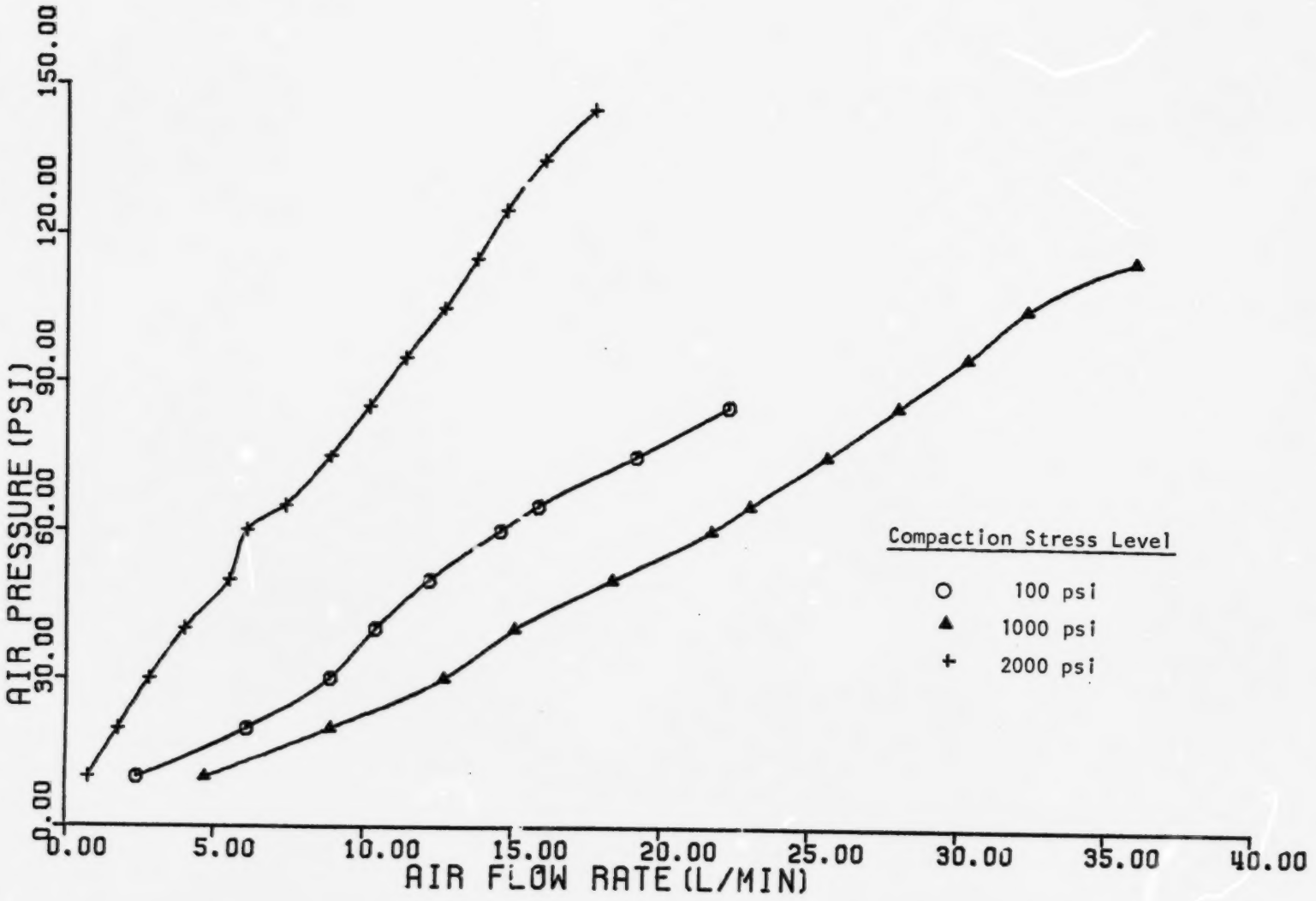

FIGURE NO. 19: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, COARSE SINGLE (1ST SERIES) SAMPLES, TESTS #109 - 111 (M/C = 14.0, 14.5 & 13.6%).

TABLE A-23: AIR PERMEABILITY DATA FOR TEST #112

COAL DESCRIPTION: Coarse, Large (As Is) Single

MOISTURE CONTENT:

Initial = 36.2%

WEIGHT OF SAMPLE = 8.93 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
12.5	0.0	0.0	0.0
10.25	100	10	13.8
		20	25.6
		30	36.6

Table A-24: AIR PERMEABILITY DATA FOR TEST #113

COAL DESCRIPTION: Coarse Large (As Is) Single

MOISTURE CONTENT:

Initial = 34.5%

WEIGHT OF SAMPLE = 9.98 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
12.5	0.0	0.0	0.0
8.19 - 8.63	1000	10	0.3
		20	1.2
		30	2.8
		40	3.6
		50	5.2
		60	6.9
		65	8.4
		75	9.9

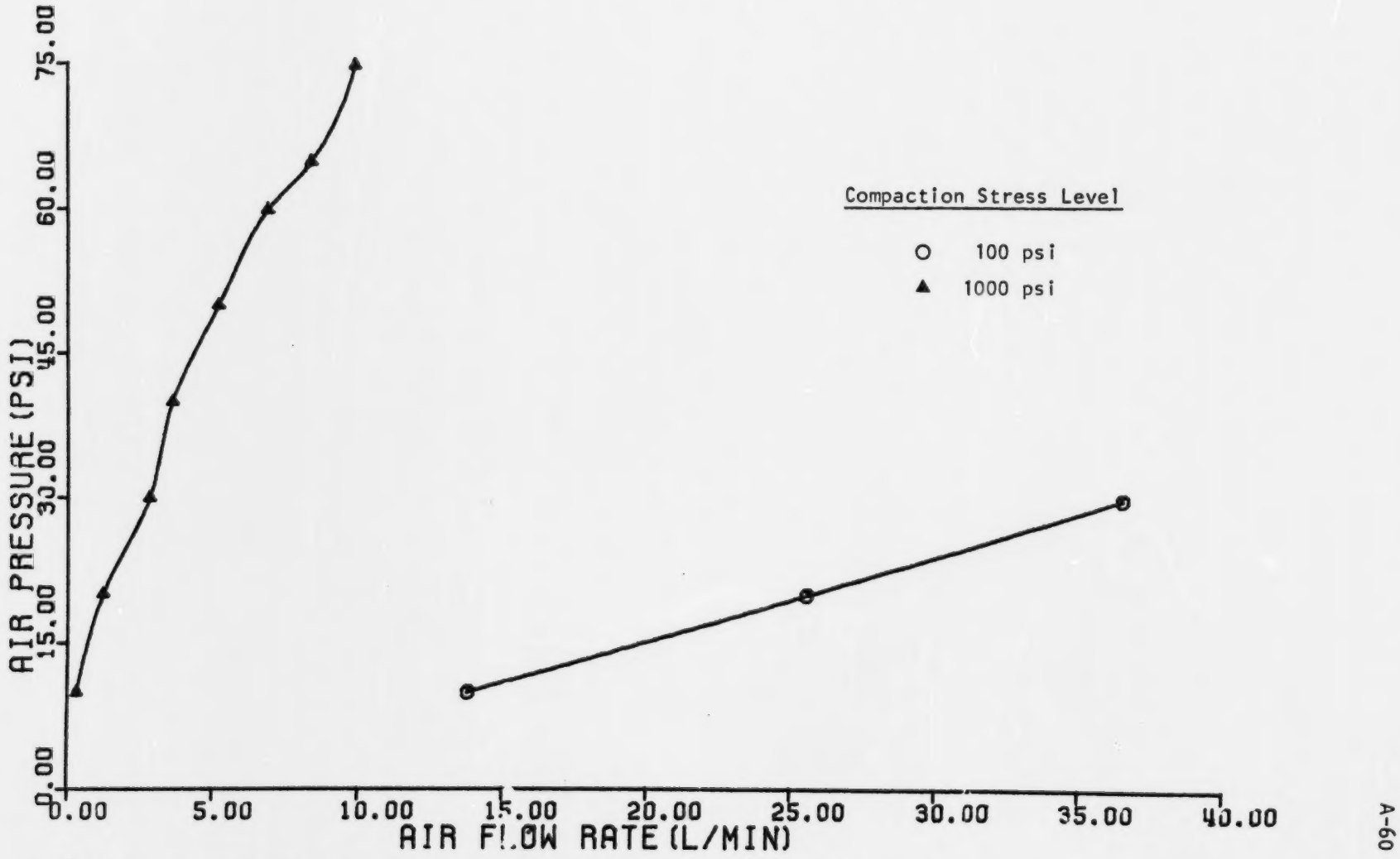

FIGURE NO. 20: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, CORASE SINGLE (1ST SERIES) SAMPLES, TESTS #112 - 113 (M/C = 36.2, 34.5%).

TABLE A-25

AIR PERMEABILITY DATA FOR TEST #118

COAL DESCRIPTION: *Fine, Large (Air Dried) Single*

MOISTURE CONTENT:

Initial = ~14%

WEIGHT OF SAMPLE = 9.73 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
13.19 - 13.25	100	10	13.2
		20	26.2
		30	36.0

TABLE A-26

AIR PERMEABILITY DATA FOR TEST #119

COAL DESCRIPTION: Fine, Large (Air Dried) Single

MOISTURE CONTENT:

Initial = ~14%

WEIGHT OF SAMPLE = 10.35 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
9.94 - 10.63	1000	10	1.2
		20	2.8
		30	5.2
		40	8.2
		50	10.4
		60	13.2
		65	18.4
		75	21.4
		85	24.8
		95	28.6
		105	31.4
		115	34.0
		125	37.1

TABLE A-27

AIR PERMEABILITY DATA FOR TEST # 120

COAL DESCRIPTION: Fine, Large (Air Dried) Single

MOISTURE CONTENT:

Initial = ~14%

WEIGHT OF SAMPLE = 9.18 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
	2000	20	0.6
		30	1.0
		40	2.8
		50	3.2

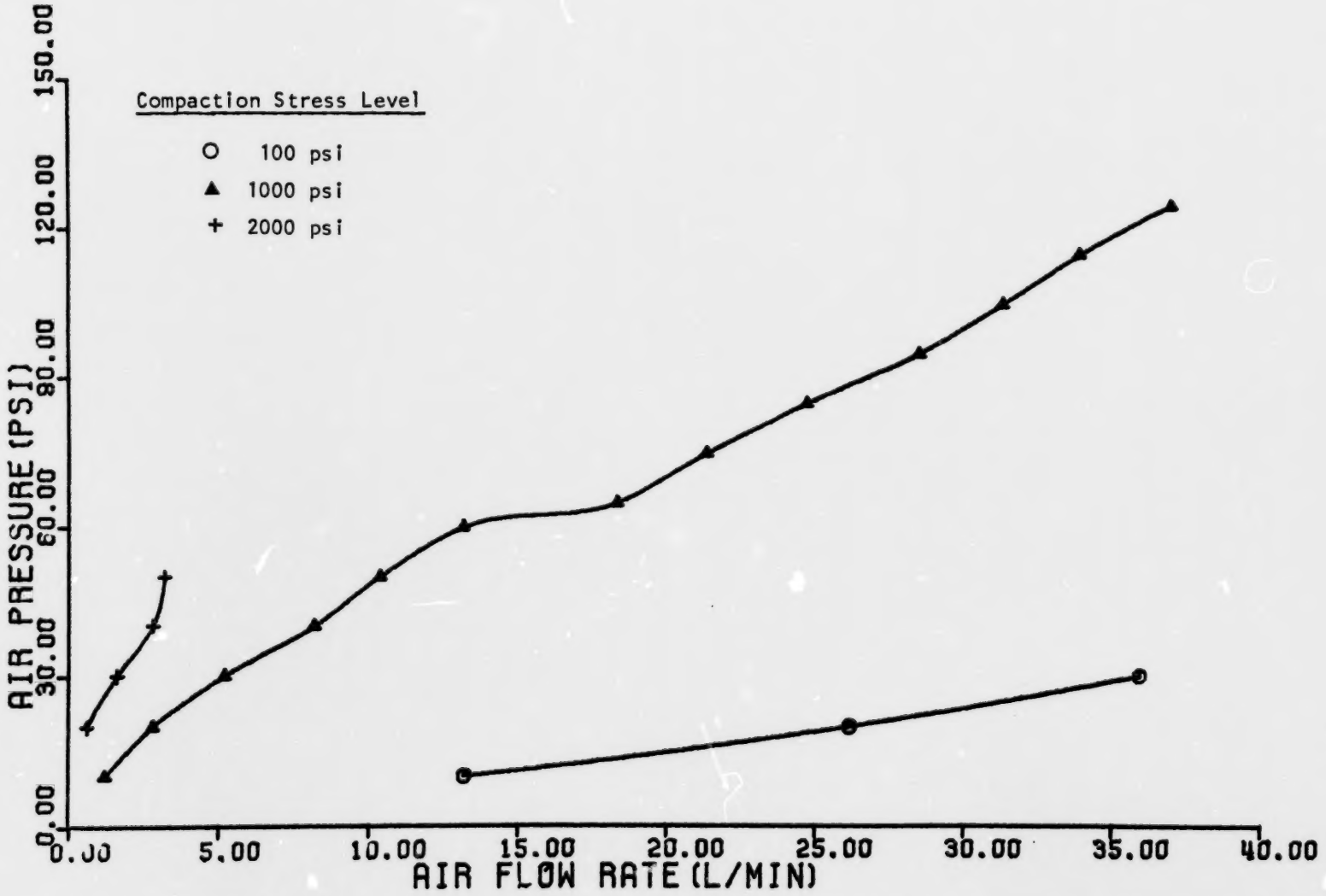

FIGURE NO. 21: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, FINE SINGLE (1ST SERIES) SAMPLES, TESTS #118 - 120 (M/C = ~14%).

TABLE A-28

AIR PERMEABILITY DATA FOR TEST #121

COAL DESCRIPTION: Fine, Large (As Is) Single

MOISTURE CONTENT:

Initial = 28.8%

WEIGHT OF SAMPLE = 11.30 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
12.38 - 12.5	100	10	5.7
		20	6.9
		30	9.6
		40	12.0
		50	13.5
		60	15.3
		65	15.9
		75	17.5

TABLE A-29

AIR PERMEABILITY DATA FOR TEST # 122

COAL DESCRIPTION: Fine, Large (As Is) Single

MOISTURE CONTENT:

Initial = 28.8%

WEIGHT OF SAMPLE =

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
10.06 - 10.25	1000	10	0.7
		20	1.4
		30	2.0
		40	3.0
		50	3.8
		60	5.0
		65	6.0
		75	6.9
		85	7.9
		95	9.1
		105	10.4
		115	11.4
		125	12.4
		135	13.8
		145	14.8

TABLE A-30

AIR PERMEABILITY DATA FOR TEST # 123

COAL DESCRIPTION: Fine, Large (As Is) Single

MOISTURE CONTENT:

Initial = 28.8%

WEIGHT OF SAMPLE = 11.67 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
14.5	0.0	0.0	0.0
9.19 - 9.38	2000	10	0.6
		20	1.2
		30	2.2
		40	3.4
		50	5.0
		60	6.9
		65	8.2
		75	9.6
		85	11.4
		95	12.7
		105	15.1
		115	17.0
		125	19.2
		135	21.2
		145	22.8

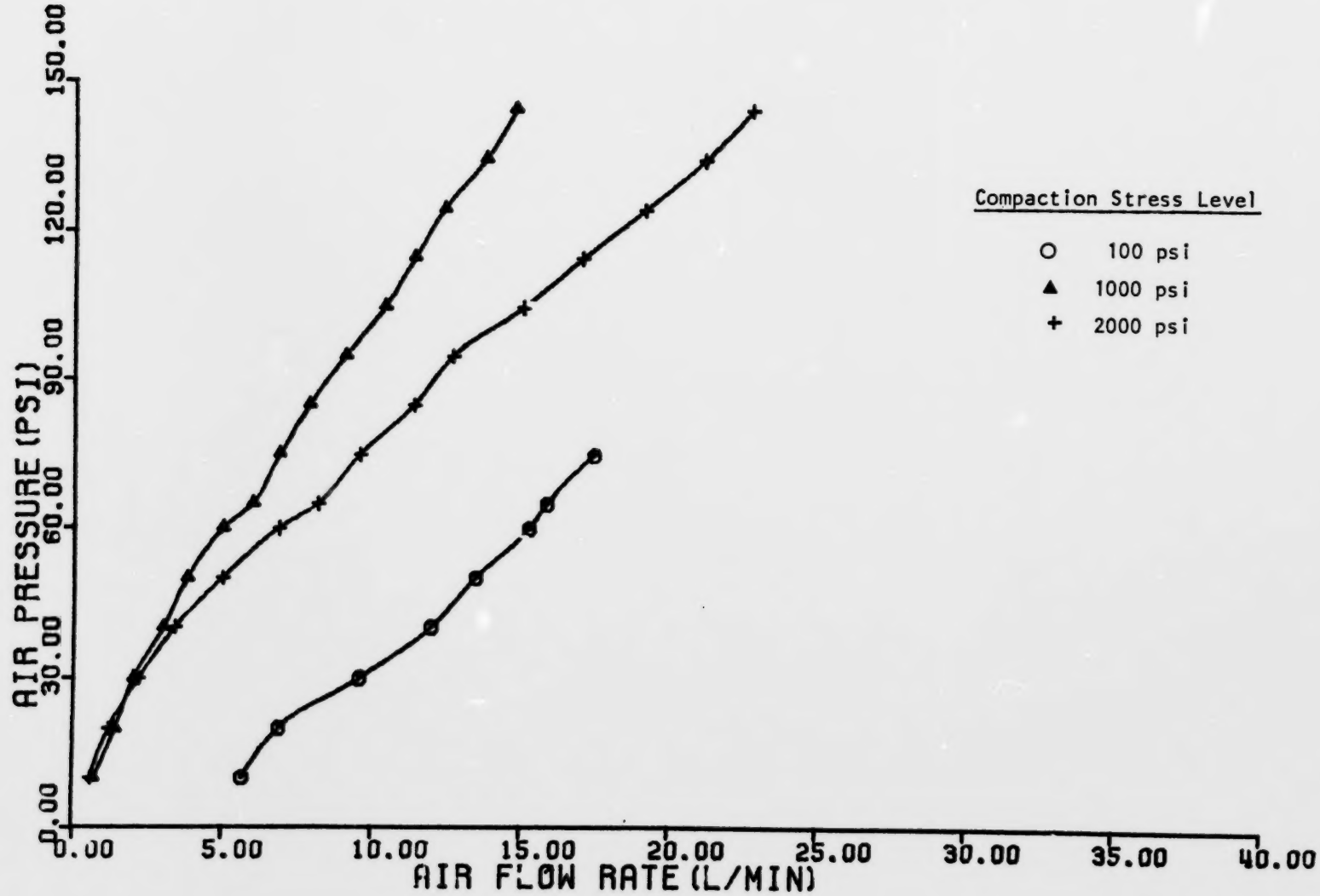

FIGURE NO. A-22: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, FINE SINGLE (1ST SERIES) SAMPLES, TEST #121 - 123 (M/C = 28.8%).

TABLE A-29

AIR PERMEABILITY DATA FOR TEST # 124

COAL DESCRIPTION: Fine, Large (Wetted) Single

MOISTURE CONTENT:

Initial = 44.3%

WEIGHT OF SAMPLE = 9.72 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
12.00	0.0	0.0	0.0
9.75	100	10	9.6
		20	17.8
		30	24.2
		40	30.9
		50	36.6

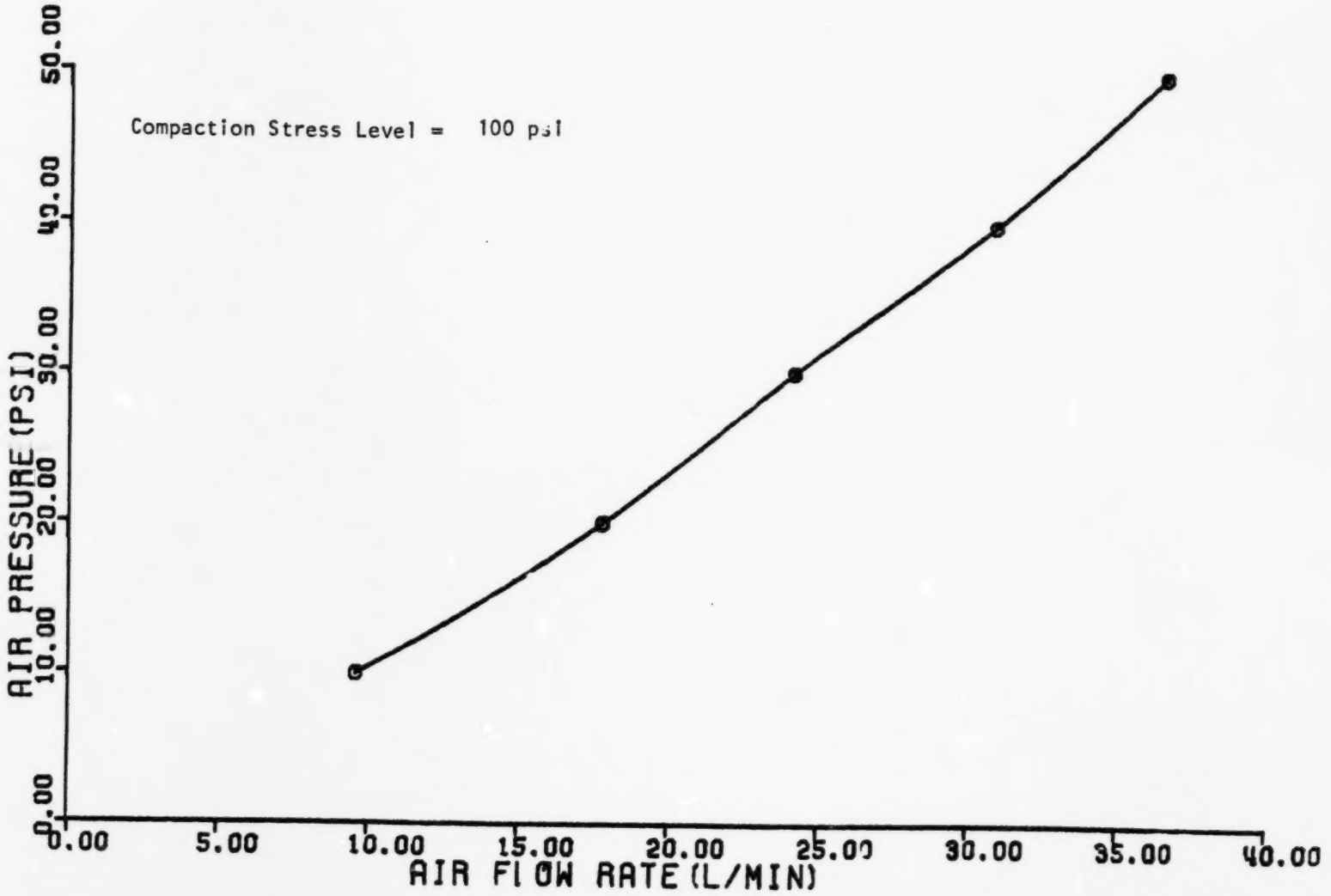

FIGURE NO. A-23: VARIATION OF FLOW RATE WITH AIR PRESSURE LEVEL FOR LARGE, FINE SINGLE (1ST SERIES) SAMPLES, TESTS #124 (M/C = 44.3%).

TABLE A-30

AIR PERMEABILITY DATA FOR TEST # 127

COAL DESCRIPTION: Small, Coarse, Single (~15%)

MOISTURE CONTENT:

Initial = 12.6%

WEIGHT OF SAMPLE = 5.36 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
7.25	0.0	0.0	0.0
6.38 - 6.5	100	10	11.6
		20	15.9
		30	20.4
		40	25.9
		50	34.0

TABLE A-31

AIR PERMEABILITY DATA FOR TEST # 128

COAL DESCRIPTION: Small, Coarse, Single (~15%)

MOISTURE CONTENT:

Initial = 13.4%

WEIGHT OF SAMPLE = 5.71 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
7.0	0.0	0.0	0.0
5.56-5.81	1000	10	5.9
		20	9.1
		30	13.0
		40	16.1
		50	18.6
		60	22.3
		65	24.8
		75	27.0
		85	29.8
		95	32.0
		105	34.6
		115	38.0

TABLE A-32

AIR PERMEABILITY DATA FOR TEST # 129

COAL DESCRIPTION: *Small, Coarse, Single*

MOISTURE CONTENT:

Initial = 13.3%

WEIGHT OF SAMPLE = 5.91 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
7.25	0.0	0.0	0.0
5.19 - 5.38	2000	10	2.8
		20	5.9
		30	8.9
		40	12.2
		50	14.8
		60	17.5
		65	19.8
		75	22.8
		85	26.2
		95	29.0
		105	32.6
		115	36.0

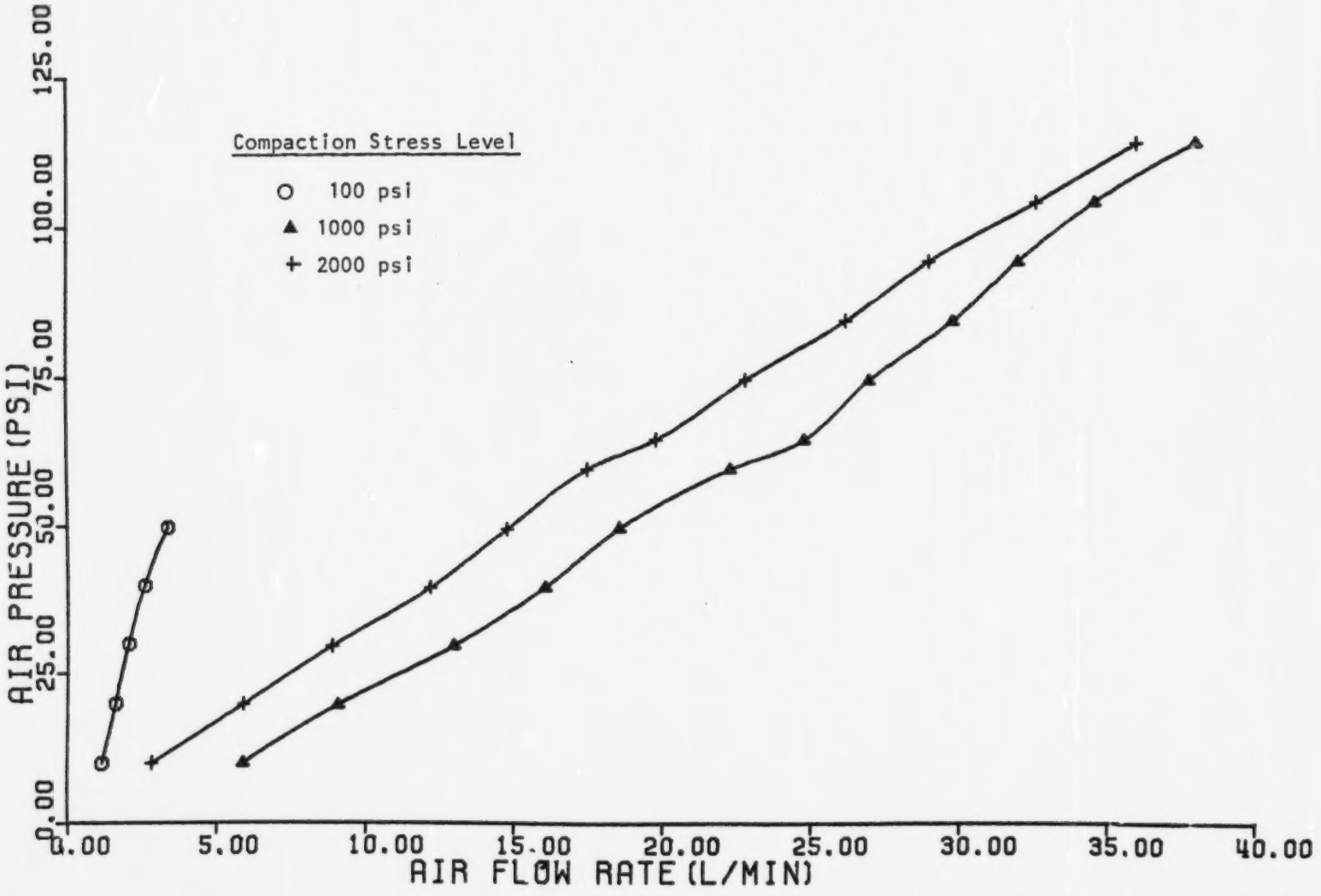

FIGURE NO. A-24: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR SMALL, COARSE SINGLE (1ST SERIES) SAMPLES, TESTS #127 - 129 (M/C = 12.6, 13.4, 13.3%).

TABLE A-33

AIR PERMEABILITY DATA FOR TEST # 130

COAL DESCRIPTION: Coarse, Small (As Is) Single

MOISTURE CONTENT:

Initial = 35.3%

WEIGHT OF SAMPLE = 7.63 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
6.19 - 6.31	100	10	2.8
		20	5.0
		30	6.9
		40	8.9
		50	10.4
		60	11.4

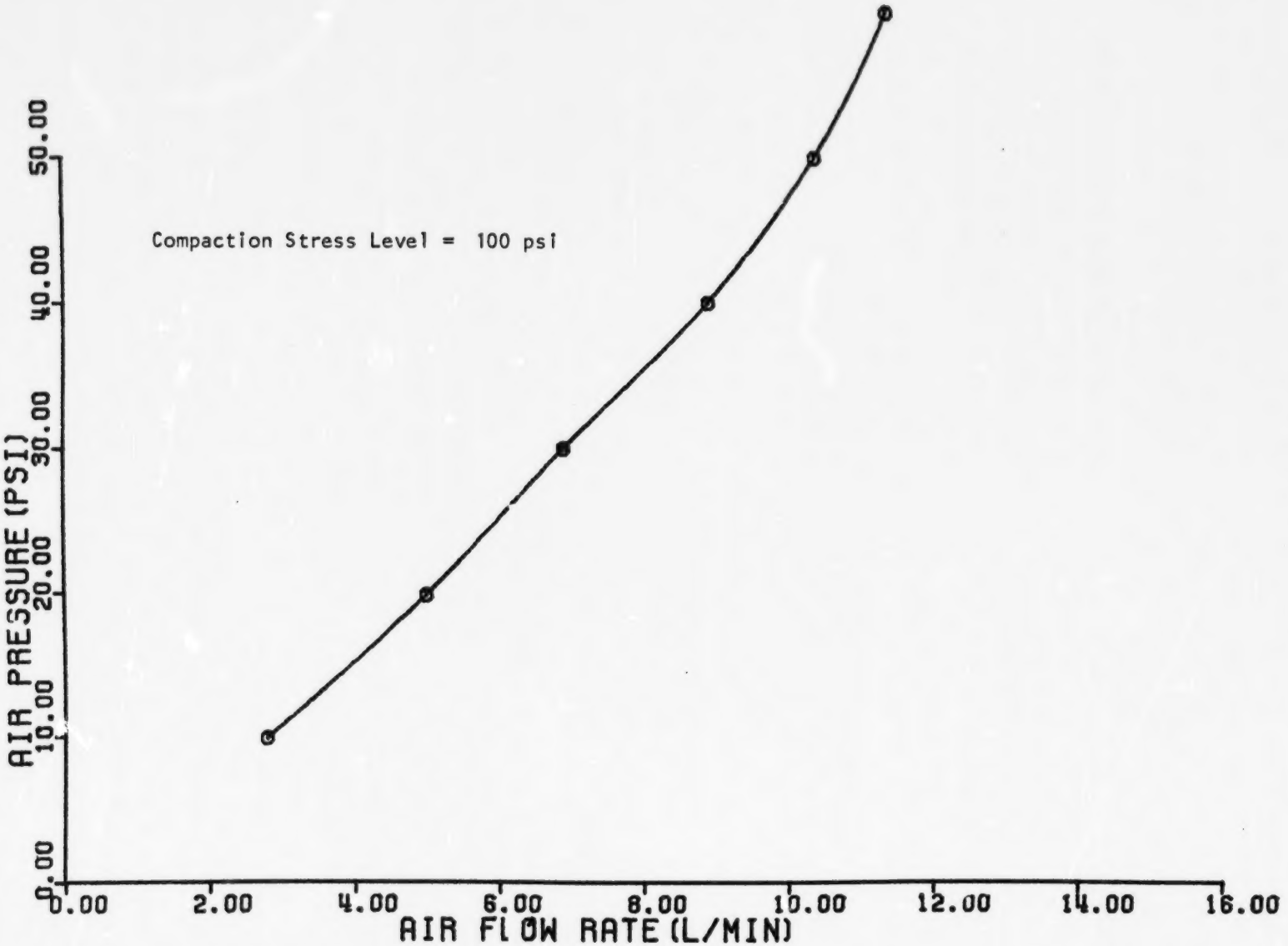

FIGURE NO. A-25: VARIATION OF FLOW RATE WITH AIR PRESSURE LEVEL FOR SMALL COARSE SINGLE (1ST SERIES) SAMPLES, TEST #130 (M/C = 35.3%).

TABLE A-34

AIR PERMEABILITY DATA FOR TEST #136

COAL DESCRIPTION: Fine, Small (Air Dried) Single

MOISTURE CONTENT:

Initial = 13.5%

WEIGHT OF SAMPLE = 5.75 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
7.25	0.0	0.0	0.0
	100	10	17.5
		20	29.8

TABLE A-35

AIR PERMEABILITY DATA FOR TEST # 137

COAL DESCRIPTION: Fine, Small (Air Dried) Single

MOISTURE CONTENT:

Initial = 15.8%

WEIGHT OF SAMPLE = 7.02 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
	1000	10	1.7
		20	4.0
		30	6.6
		40	9.4
		50	12.0
		60	14.8
		65	17.8
		75	21.2
		85	24.5
		95	27.5
		105	29.8
		115	33.1
		125	36.0

TABLE A-36

AIR PERMEABILITY DATA FOR TEST # 138

COAL DESCRIPTION: Fine, Small (Air Dried) Single

MOISTURE CONTENT:

Initial = 12.0%

WEIGHT OF SAMPLE = 5.53 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
7.25	0.0	0.0	0.0
	2000	10	3.0
		20	6.9
		30	11.1
		40	15.3
		50	20.1
		60	24.0
		65	27.3
		75	31.2
		85	33.4
		95	36.0

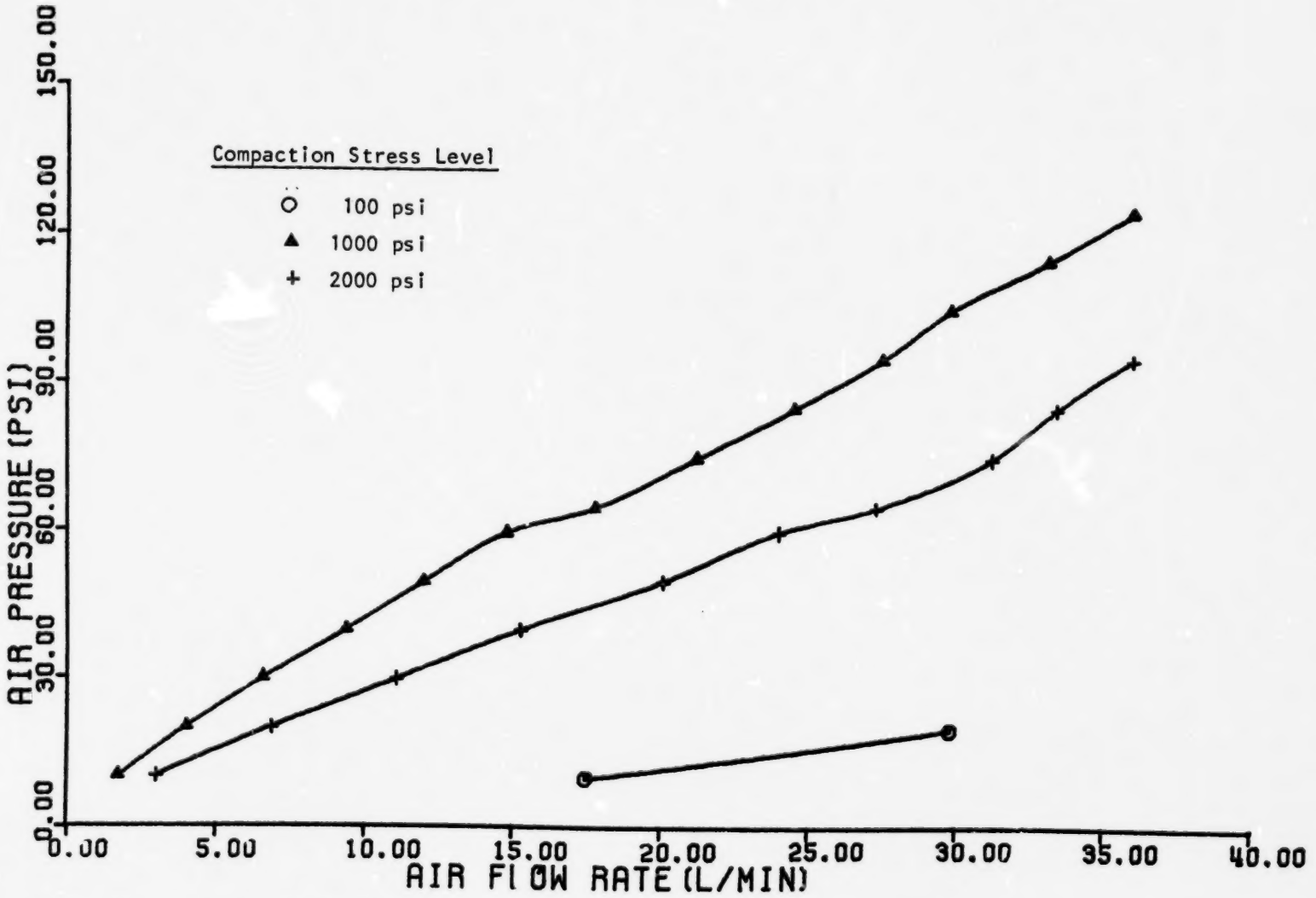

FIGURE NO. A-26: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR SMALL, FINE SINGLE (1ST SERIES) SAMPLES, TESTS #136 - 138 (M/C = 13.5, 15.8 and 12.0%).

TABLE A-37

AIR PERMEABILITY DATA FOR TEST #139

COAL DESCRIPTION: Fine Small (As is) Single

MOISTURE CONTENT:

Initial = 28.8%

WEIGHT OF SAMPLE = 6.32 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0	0	0.0
	100	10	5.7
		20	14.0
		30	22.3
		40	25.1
		50	31.7
		60	36.6

TABLE A-38

AIR PERMEABILITY DATA FOR TEST #140

COAL DESCRIPTION: Fine Small (As is) Single

MOISTURE CONTENT:

Initial = 28.8%

WEIGHT OF SAMPLE = 6.03 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min.)
8.0	0.0	0.0	0.0
5.63 - 6.0	1000	10	1.4
		20	2.8
		30	4.7
		40	7.4
		50	10.2
		60	12.1
		65	14.0
		75	16.4
		85	18.4
		95	19.8
		105	21.4
		115	25.9
		125	29.0
		135	31.4
		145	36.6

TABLE A-39

AIR PERMEABILITY DATA FOR TEST #141

COAL DESCRIPTION: Fine Small (As is) Single

MOISTURE CONTENT:

Initial = 28.8%

WEIGHT OF SAMPLE = 5.79 lbs.

AREA = 28 sq. in.

HEIGHT OF SAMPLE (inches)	COMPACTION PRESSURE (psi)	AIR PRESSURE HEAD (psi)	FLOW RATE (L/min)
8.0	0.0	0.0	0.0
5.25 - 5.56	2000	10	0.034
		20	0.065
		30	0.250
		40	0.450
		50	0.6
		60	0.8
		65	0.95
		75	1.2
		85	1.4
		95	1.75
		105	2.2
		115	2.55
		125	2.95

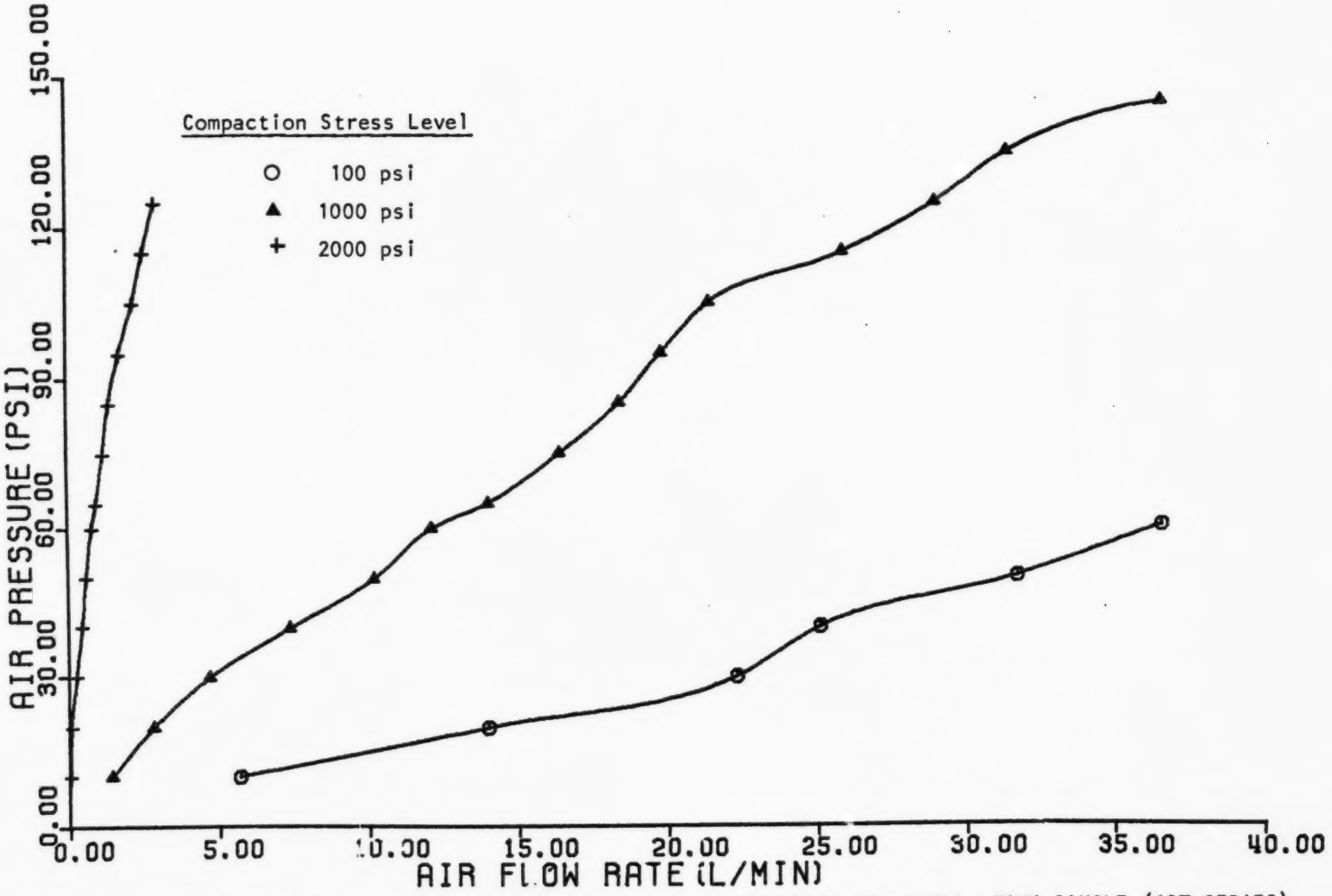

FIGURE NO. A-27: VARIATION IN FLOW RATE WITH AIR PRESSURE LEVEL FOR SMALL, FINE SINGLE (1ST SERIES) SAMPLES, TESTS #139 - 141 (M/C = 28.8%).

APPENDIX "B"

COMPACTION STRESS HISTORY

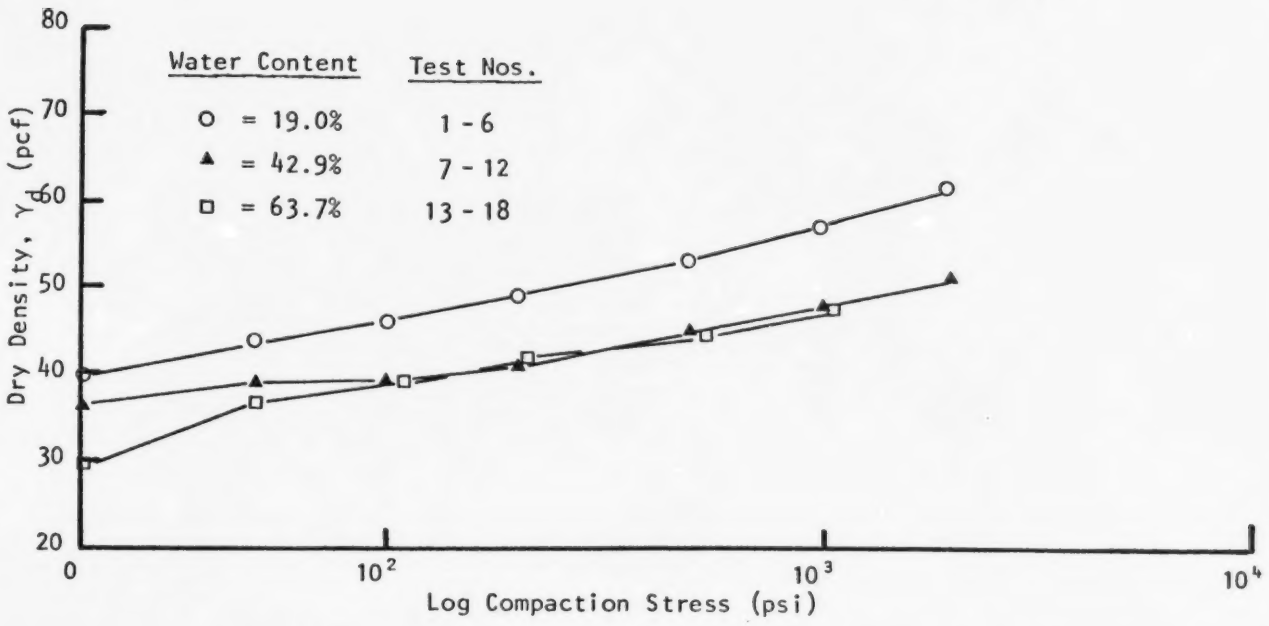

FIGURE NO. B-1: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR LARGE FINE INCREMENTAL SAMPLES (1ST SERIES).

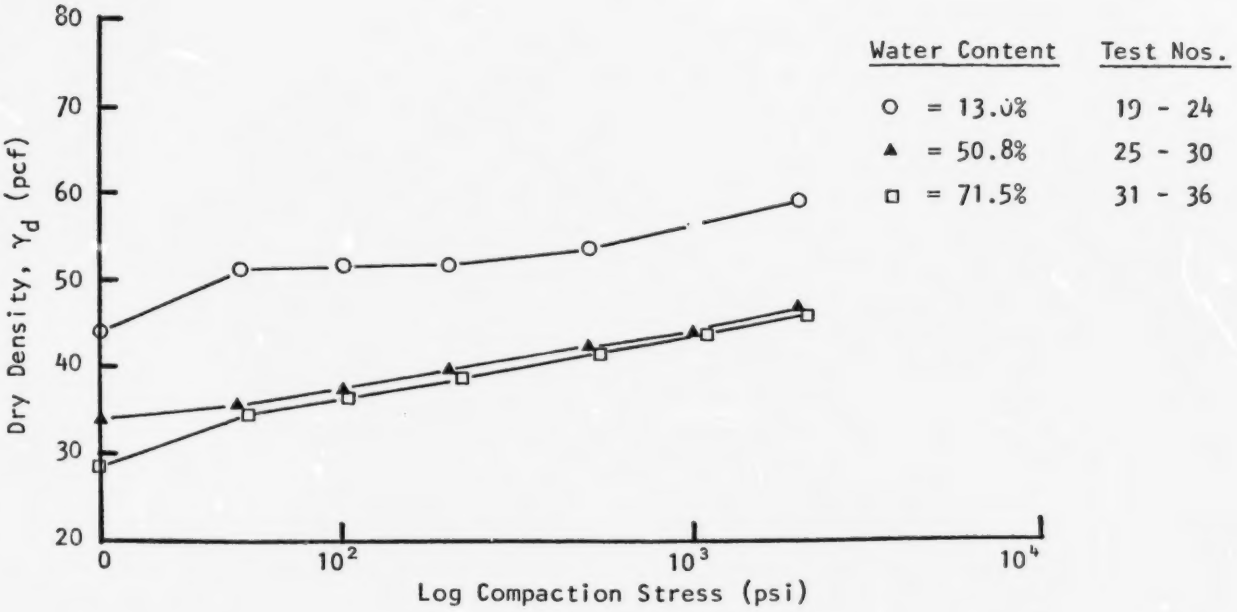

FIGURE NO. B-2: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR LARGE COARSE INCREMENTAL SAMPLES (1ST SERIES).

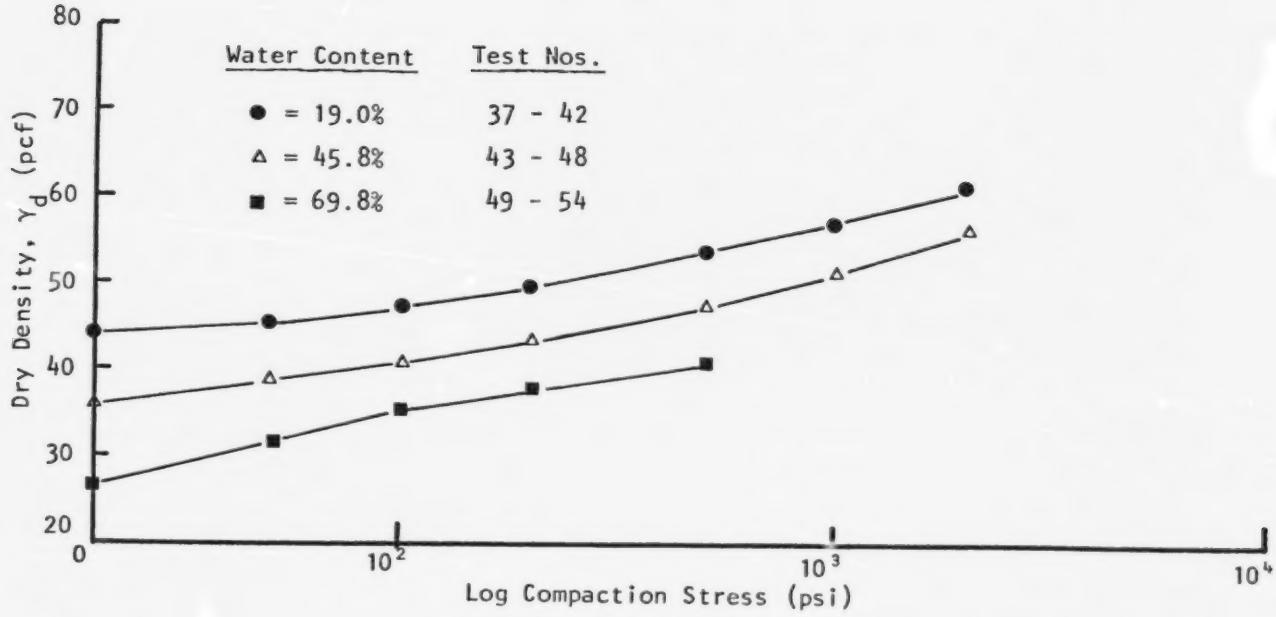

FIGURE NO. B-3: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR SMALL, FINE INCREMENTAL SAMPLES (1ST SERIES).

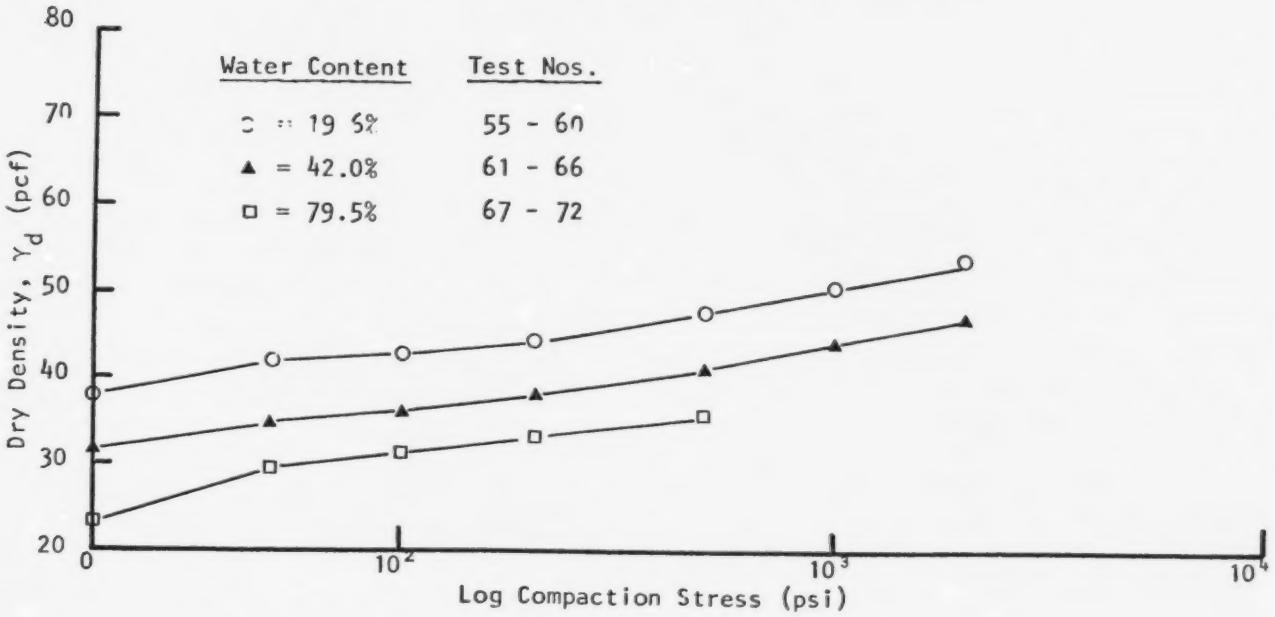

FIGURE NO. B-4: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR SMALL, FINE INCREMENTAL SAMPLES (2ND SERIES).

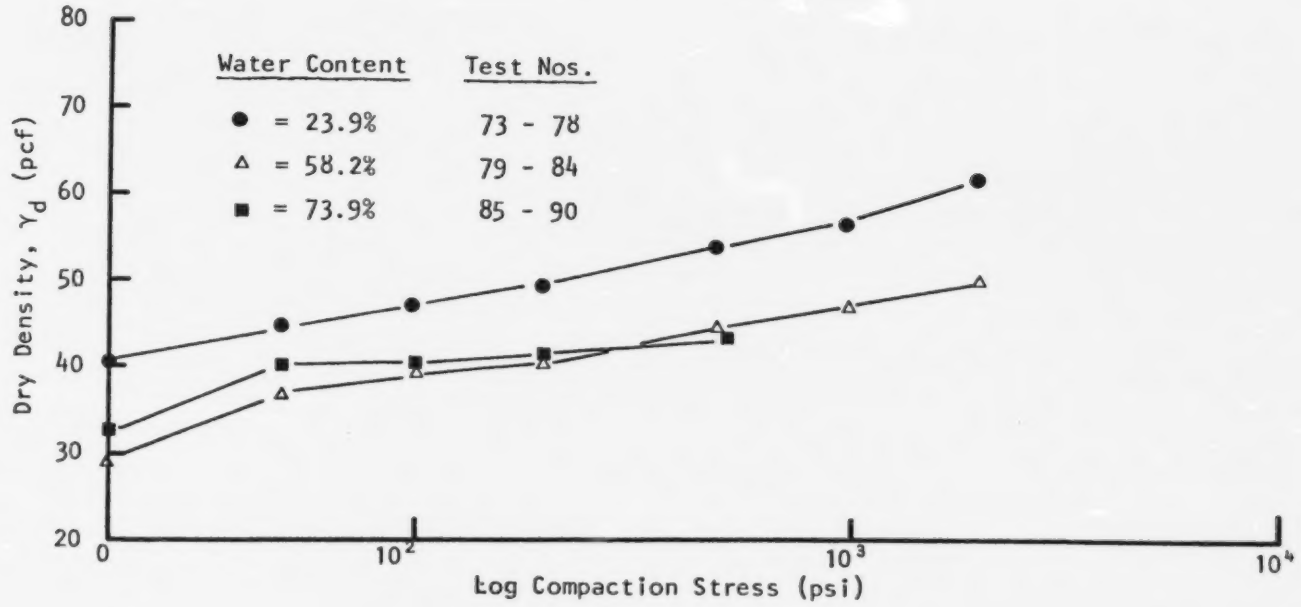

FIGURE NO. B-5: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR SMALL, COARSE INCREMENTAL SAMPLES (1ST SERIES).

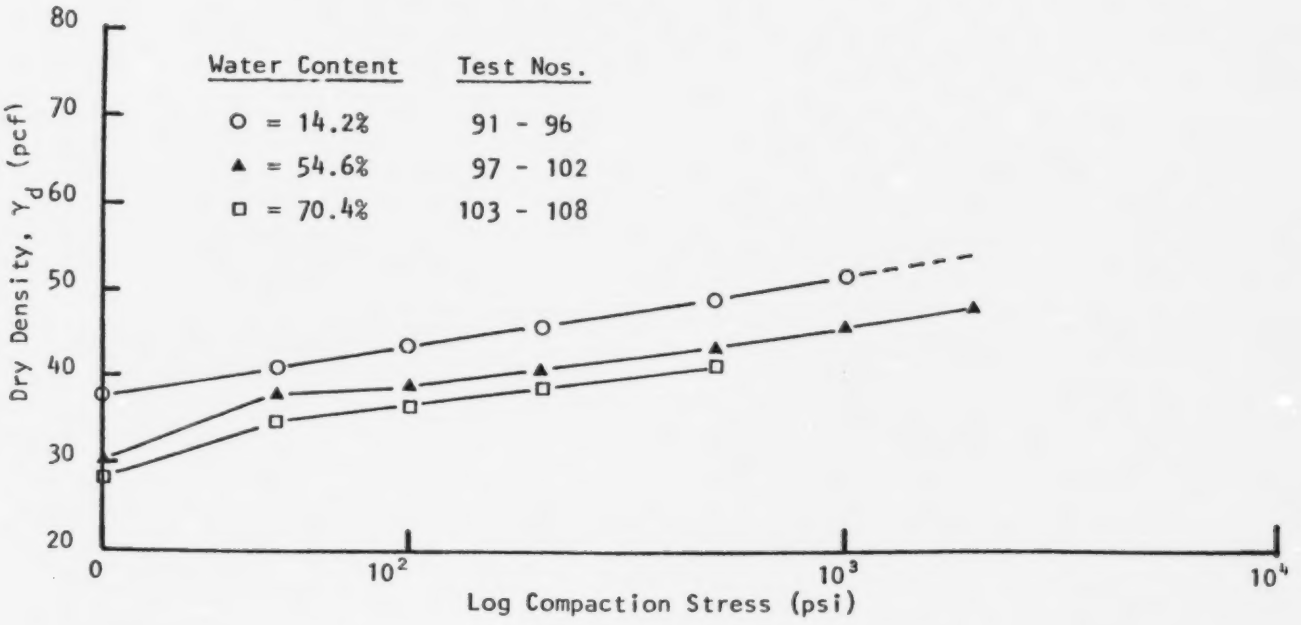

FIGURE NO. B-6: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR SMALL, COARSE INCREMENTAL SAMPLES (2ND SERIES).

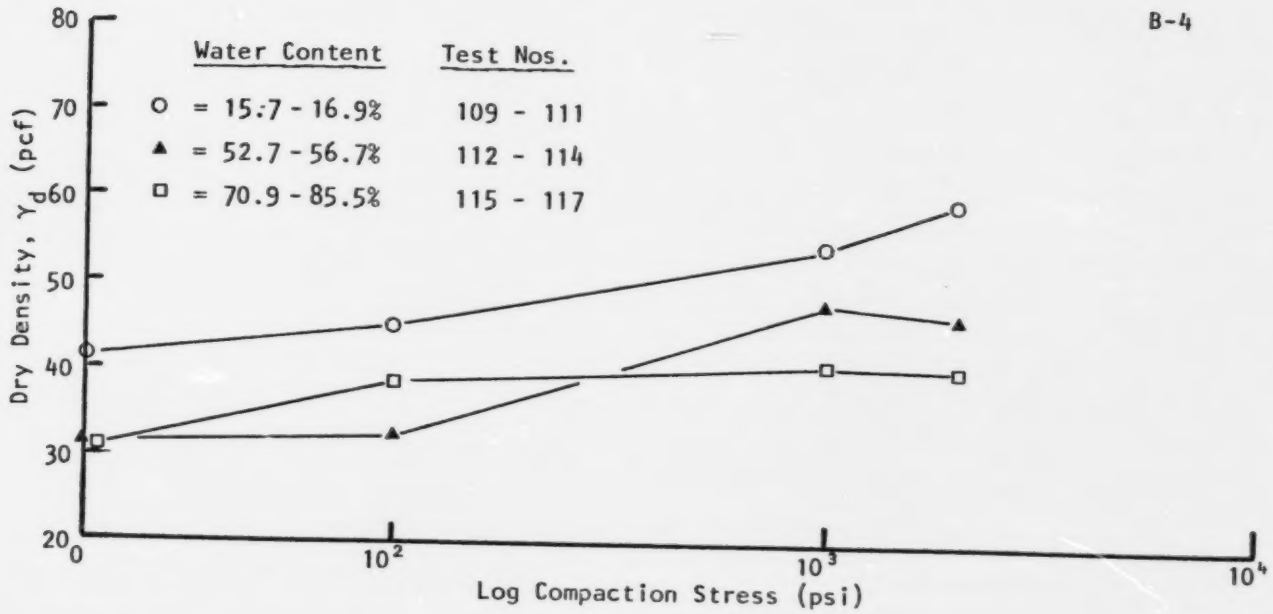

FIGURE NO. B-7: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR LARGE, COARSE, SINGLE TESTS (1ST SERIES).

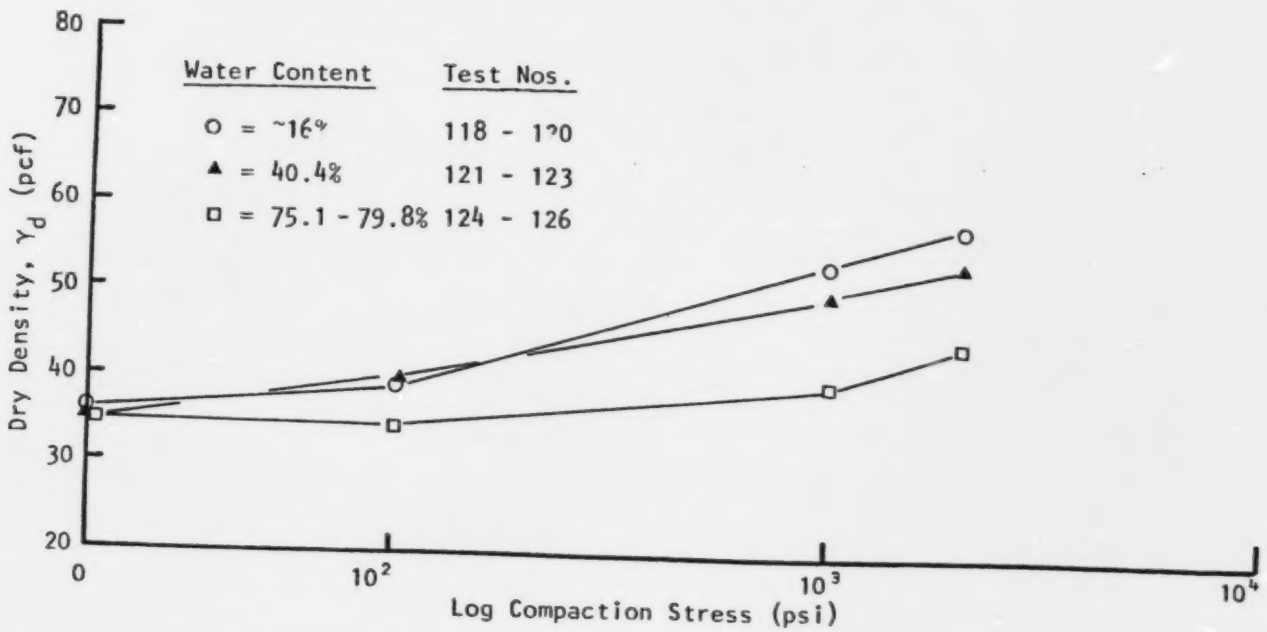

FIGURE NO. B-8: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR LARGE, FINE, SINGLE TESTS (1ST SERIES).

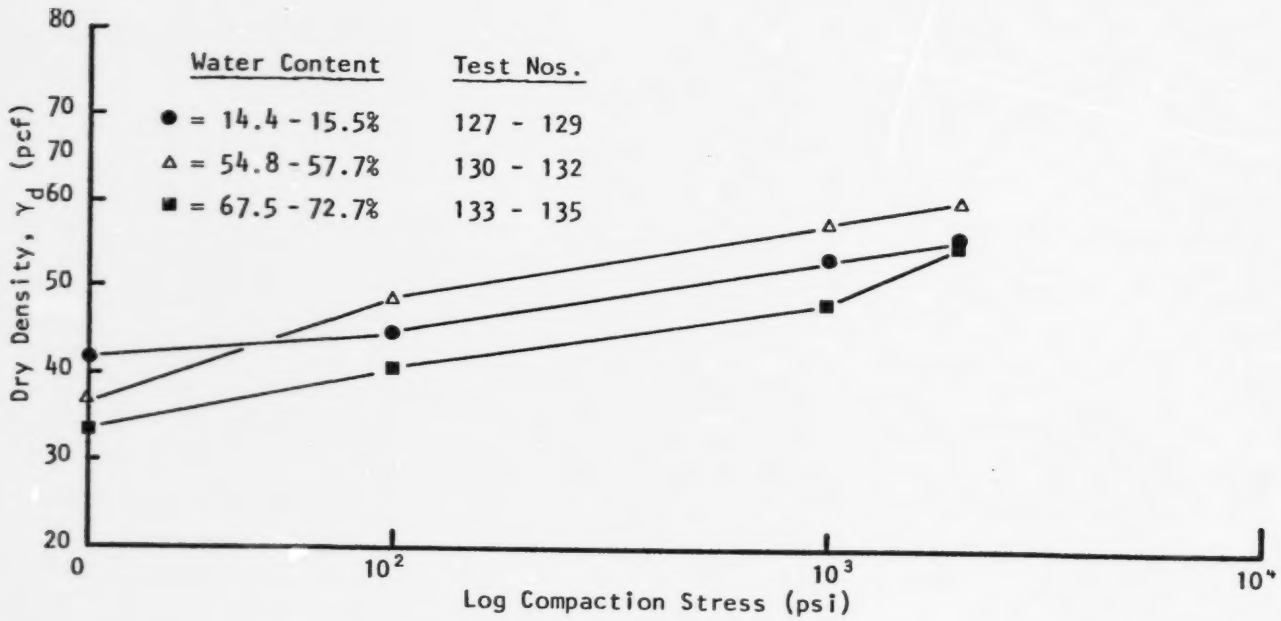

FIGURE NO. B-9: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR SMALL, COARSE, SINGLE TESTS (1ST SERIES).

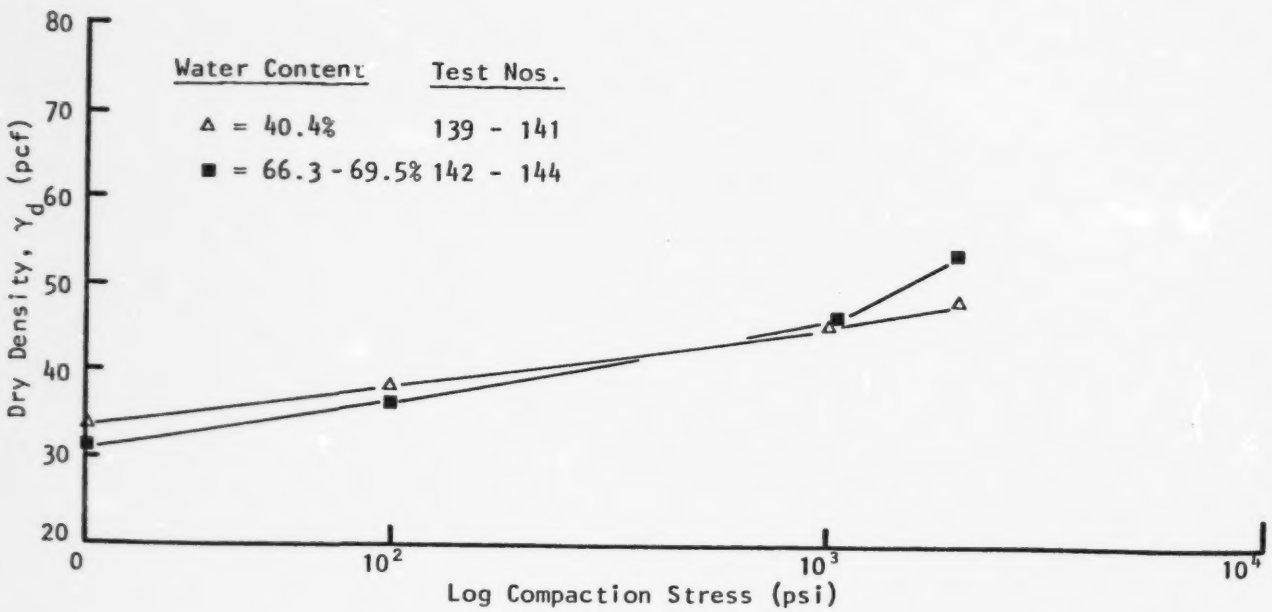

FIGURE NO. B-10: VARIATION IN DRY DENSITY WITH COMPACTION STRESS LEVEL FOR SMALL, FINE, SINGLE TESTS (1ST SERIES).

Appendix "C"

Relationship Between
Permeability and Practical Parameters
of
Dry Density and Compaction Stress

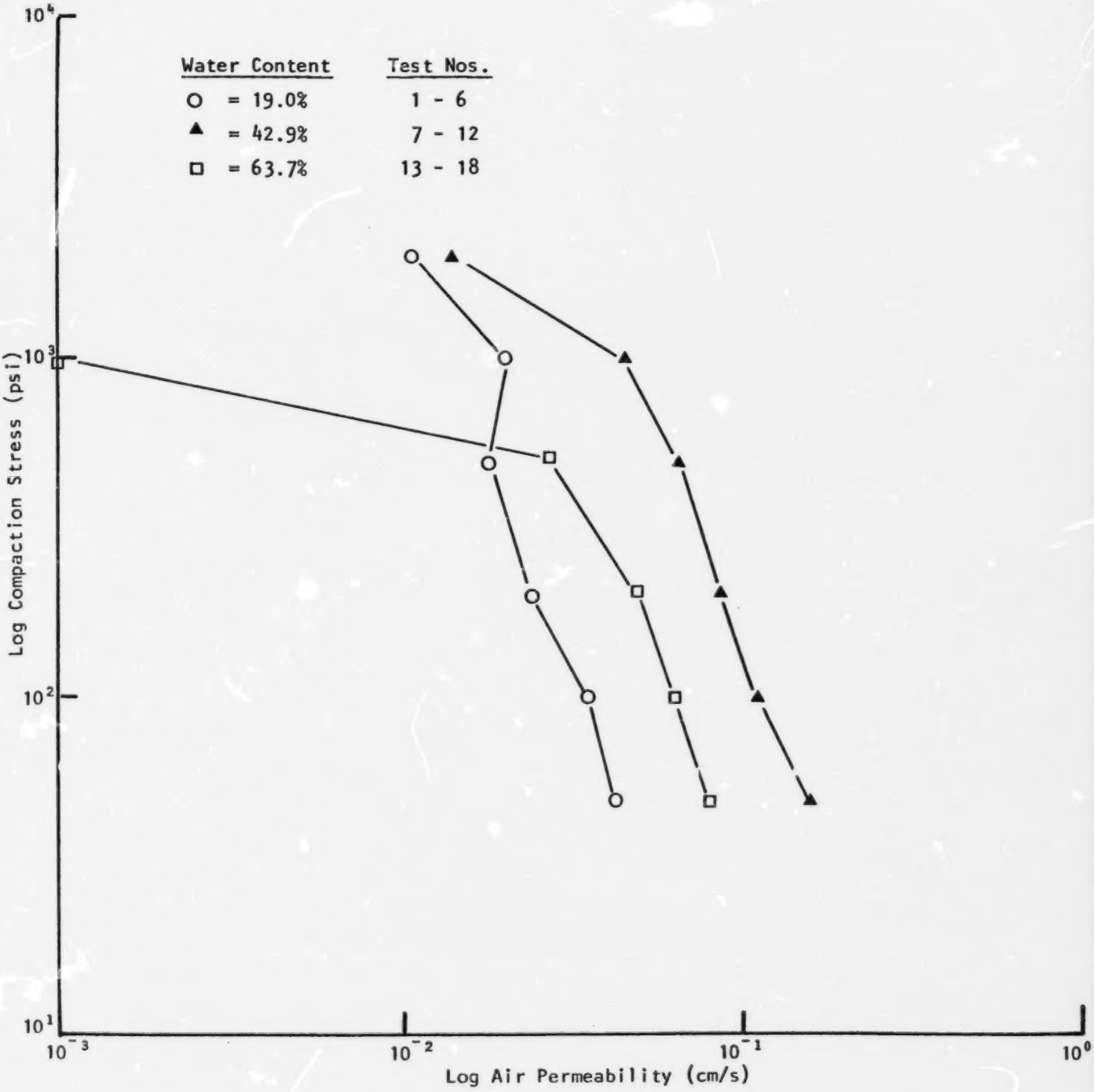

FIGURE NO. C-1: INFLUENCE OF COMPACTION STRESS ON THE AIR PERMEABILITY FOR LARGE, FINE, INCREMENTAL TESTS (1ST SERIES).

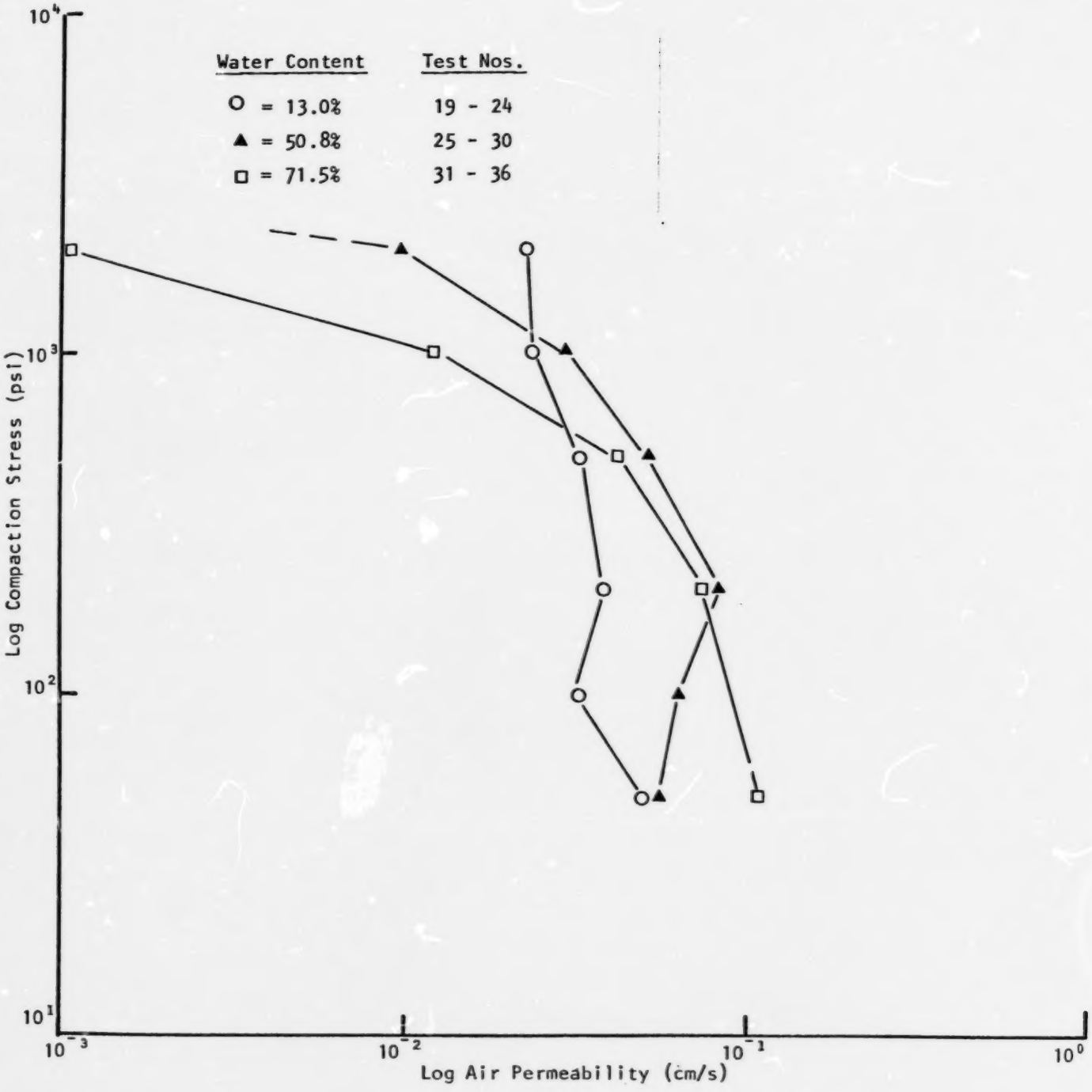

FIGURE NO. C-2: INFLUENCE OF COMPACTION STRESS ON THE AIR PERMEABILITY FOR LARGE, COARSE, INCREMENTAL TESTS (1ST SERIES).

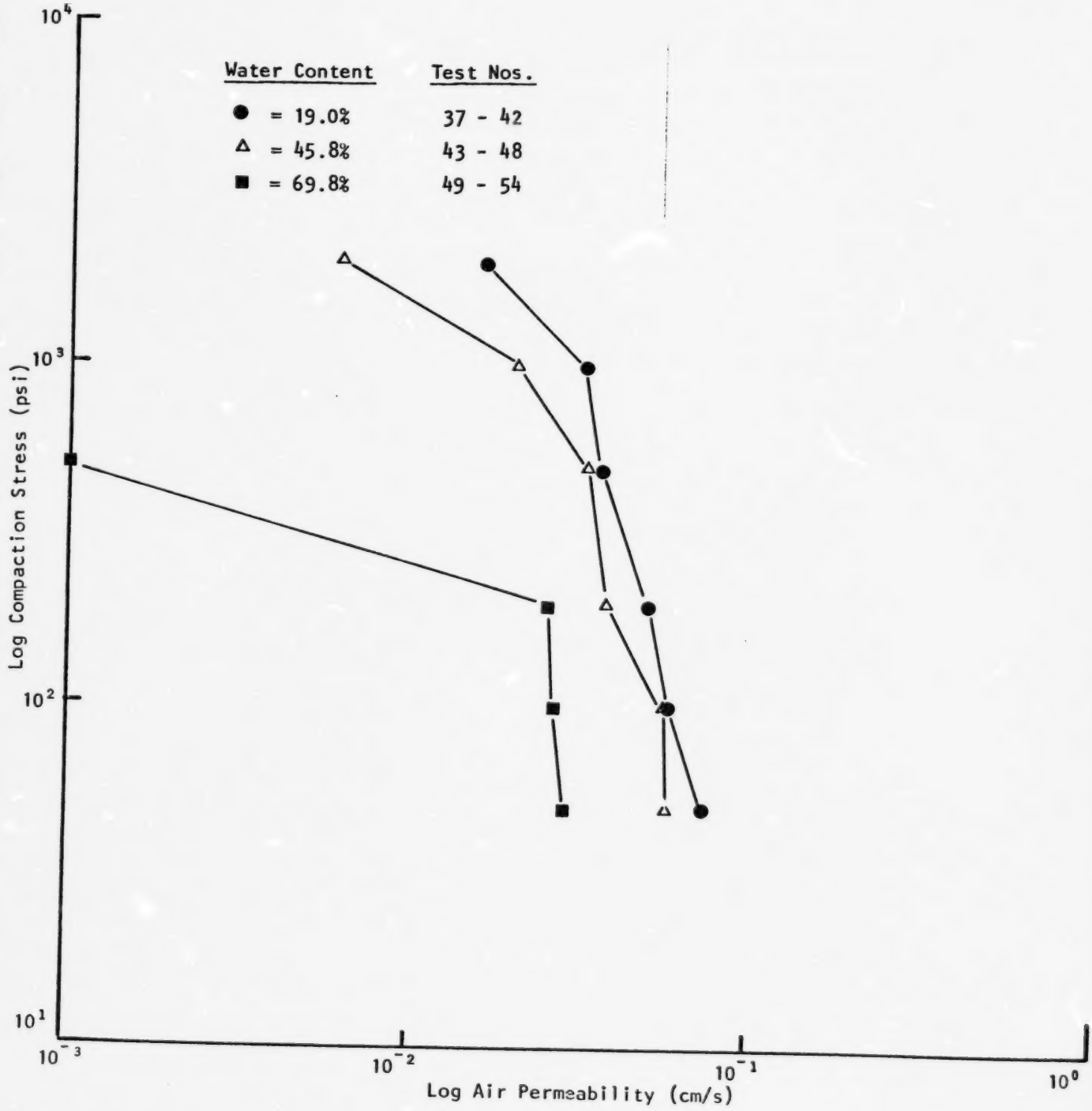

FIGURE NO. C-3: INFLUENCE OF THE COMPACTION STRESS ON THE AIR PERMEABILITY FOR SMALL, FINE, INCREMENTAL TESTS (1ST SERIES).

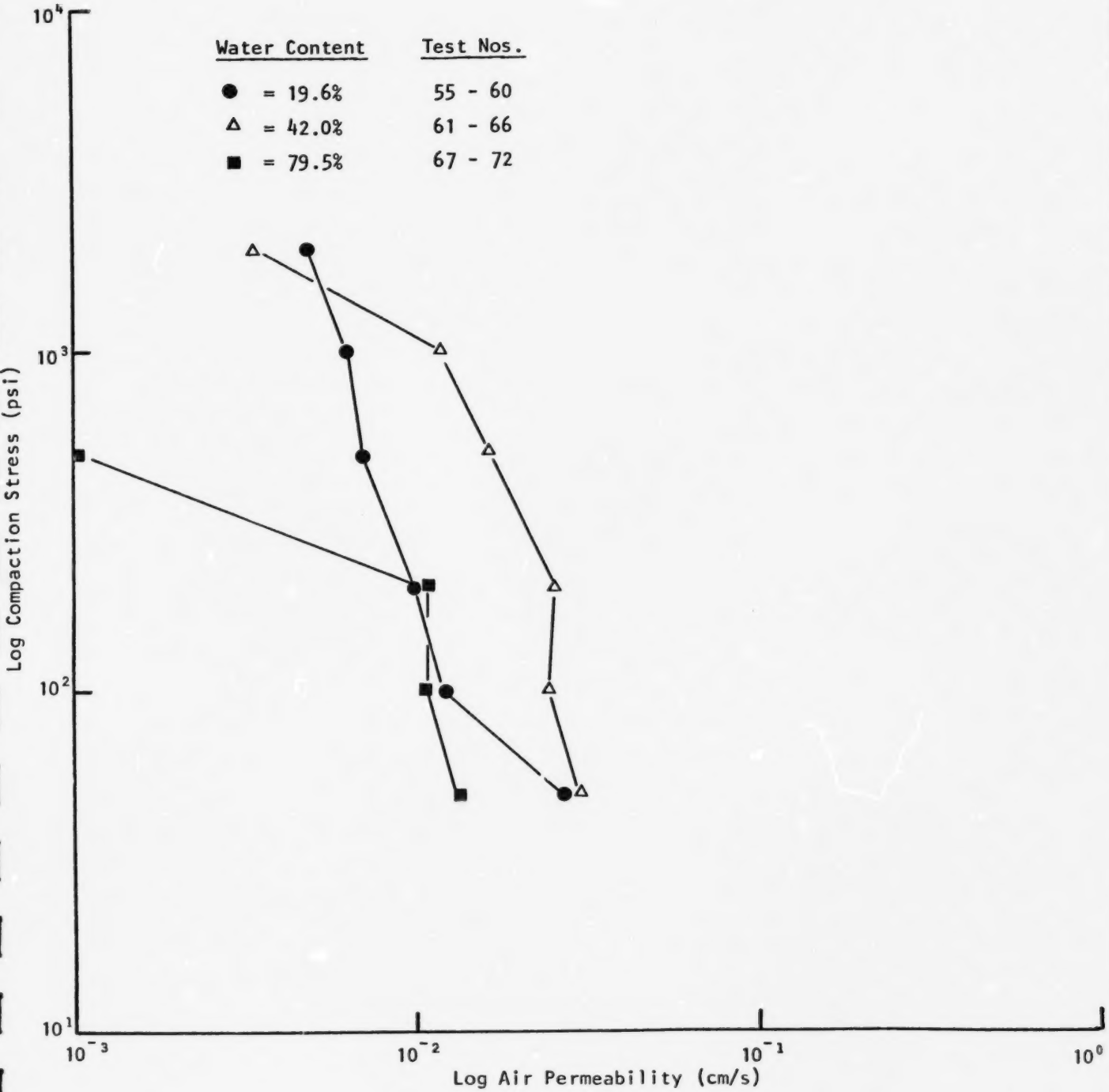

FIGURE NO. C-4: INFLUENCE OF THE COMPACTION STRESS ON THE AIR PERMEABILITY FOR SMALL, FINE, INCREMENTAL TESTS (2ND SERIES).

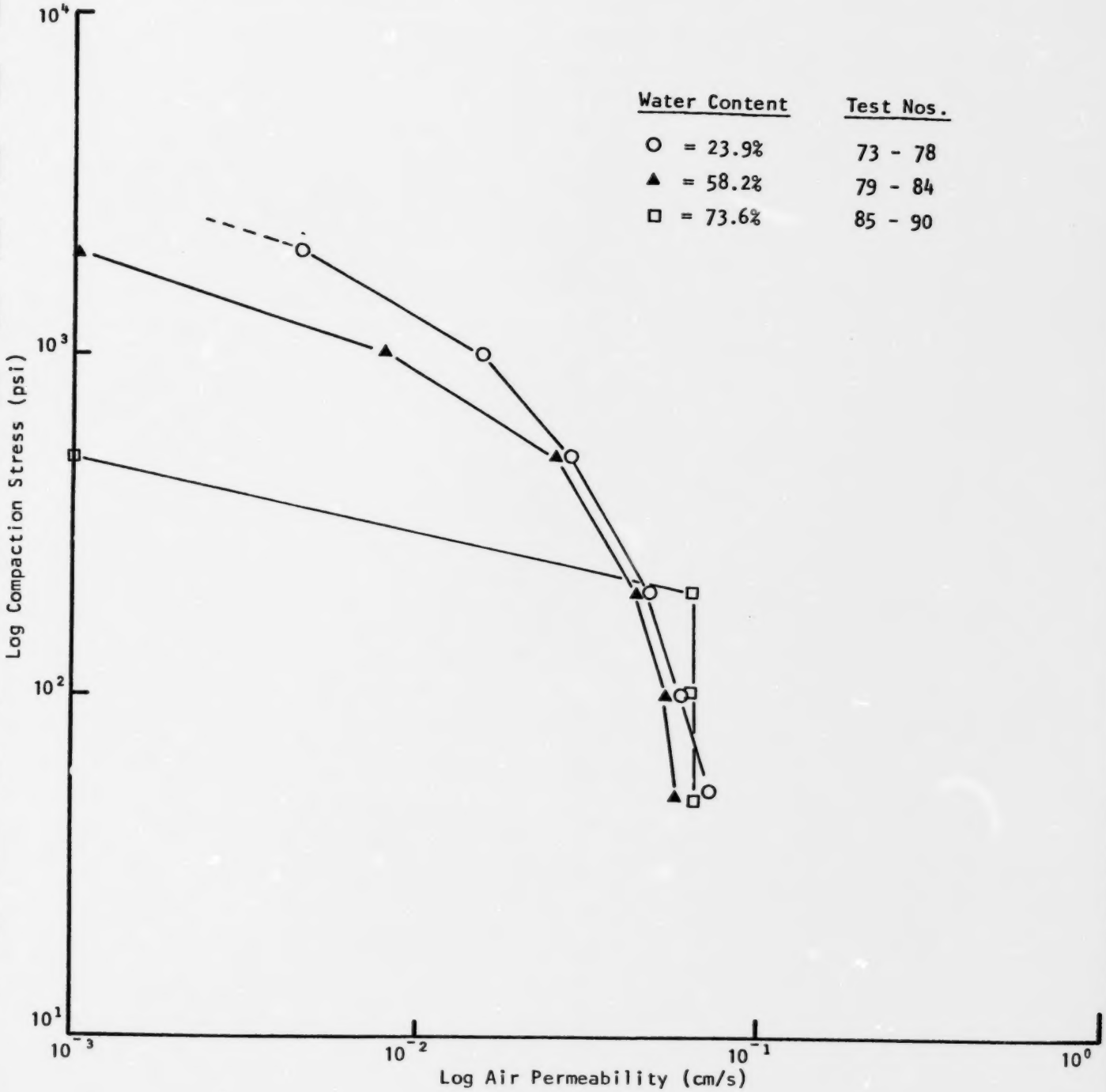

FIGURE NO. C-5: INFLUENCE OF THE COMPACTION STRESS ON THE AIR PERMEABILITY FOR SMALL, COARSE, INCREMENTAL TESTS (1ST SERIES).

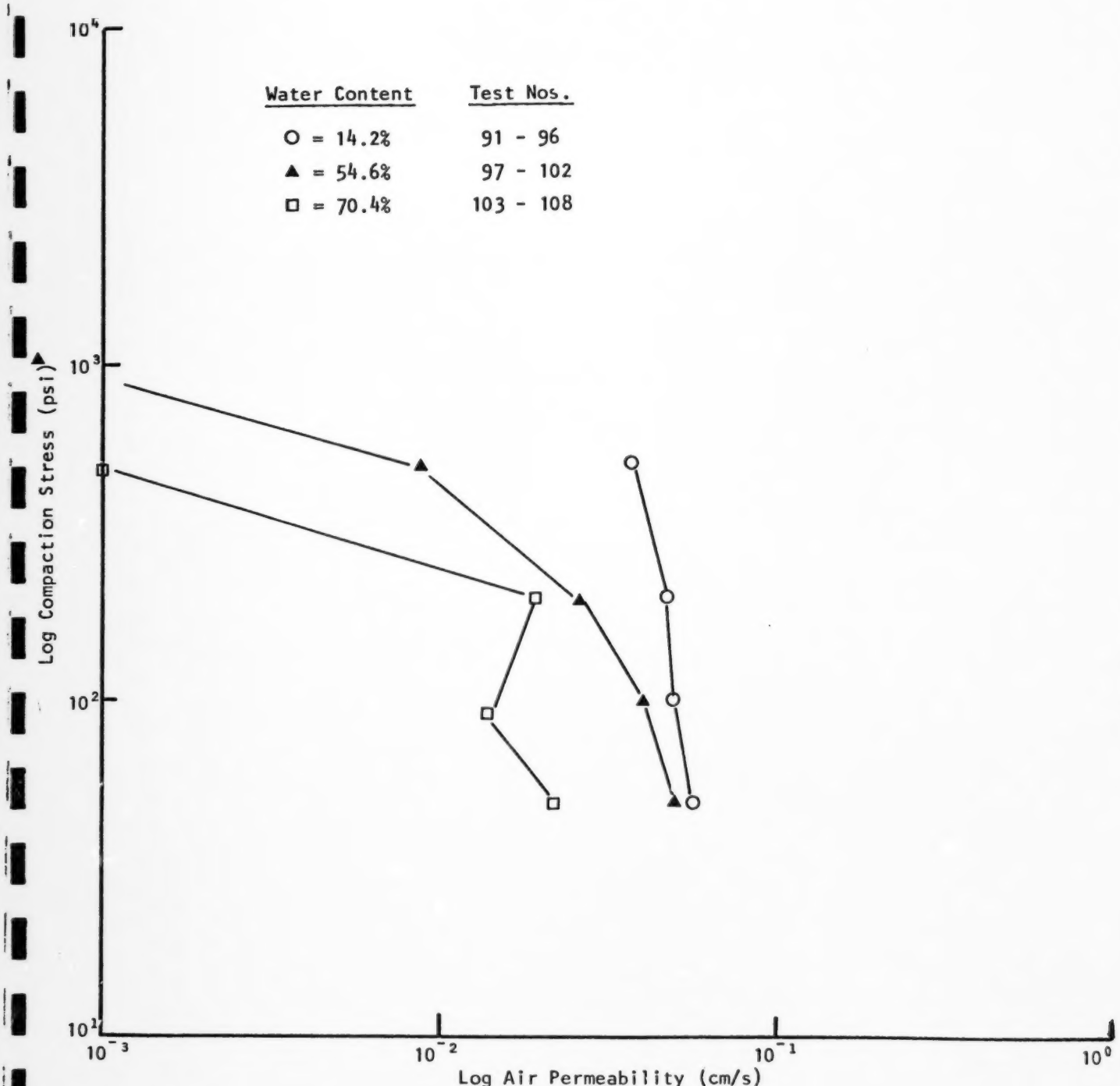

FIGURE NO. C-6: INFLUENCE OF THE COMPACTION STRESS ON THE AIR PERMEABILITY FOR SMALL, COARSE, INCREMENTAL TESTS (2ND SERIES).

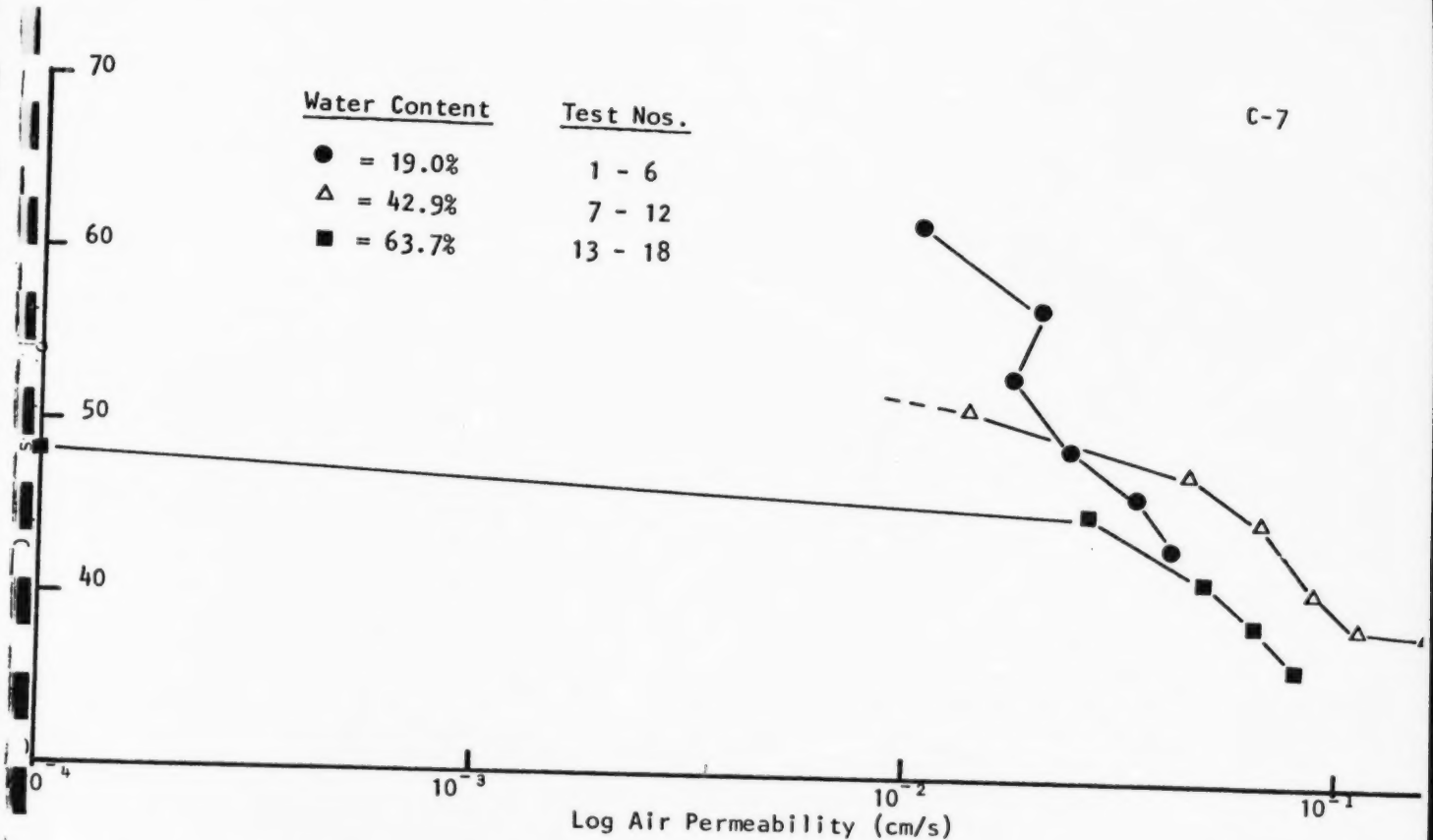

FIGURE NO. C-7: INFLUENCE OF DRY DENSITY ON THE AIR PERMEABILITY FOR LARGE, FINE, INCREMENTAL TESTS (1ST SERIES).

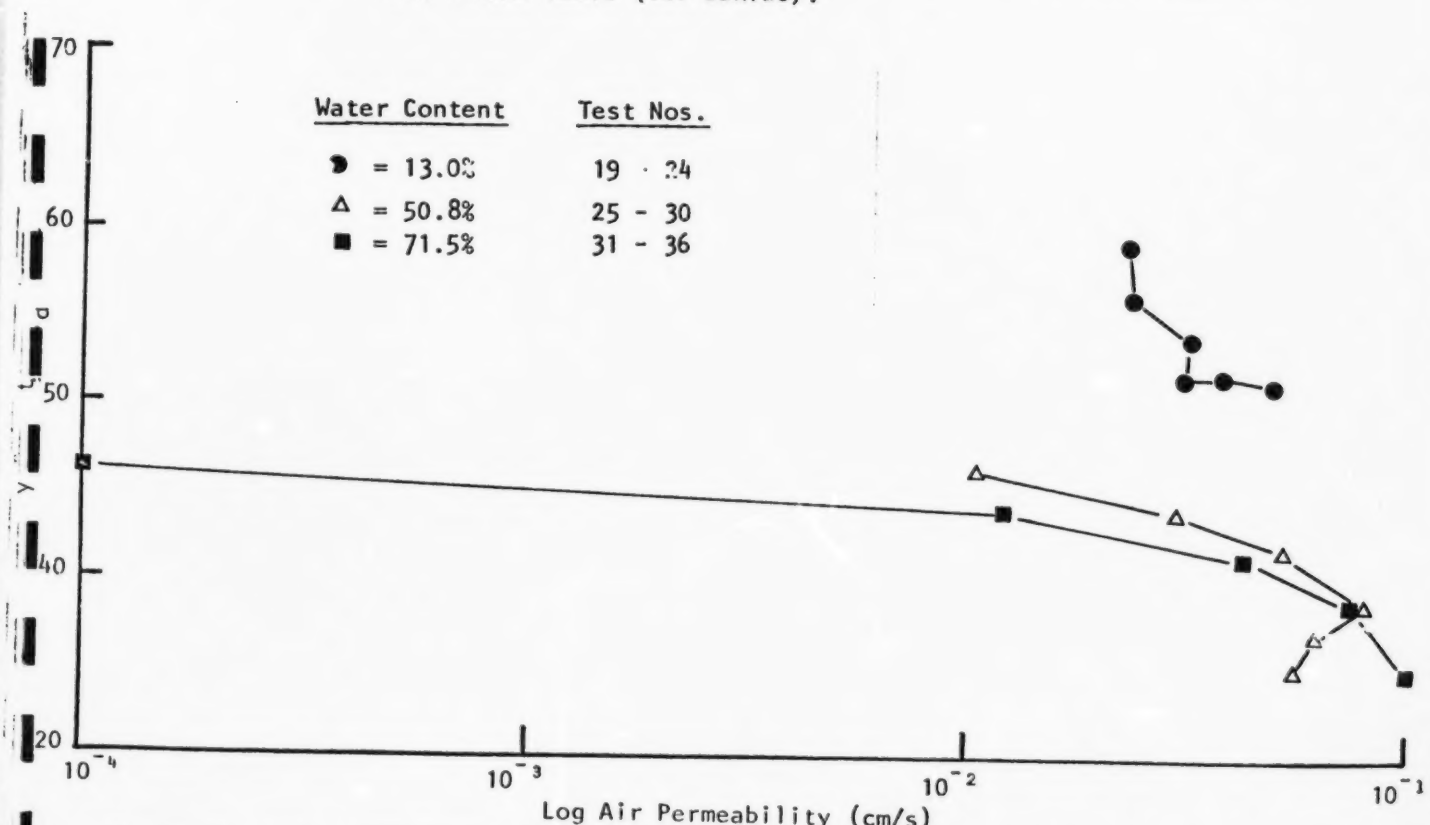

FIGURE NO. C-8: INFLUENCE OF DRY DENSITY ON THE AIR PERMEABILITY FOR LARGE, COARSE, INCREMENTAL TESTS (1ST SERIES).

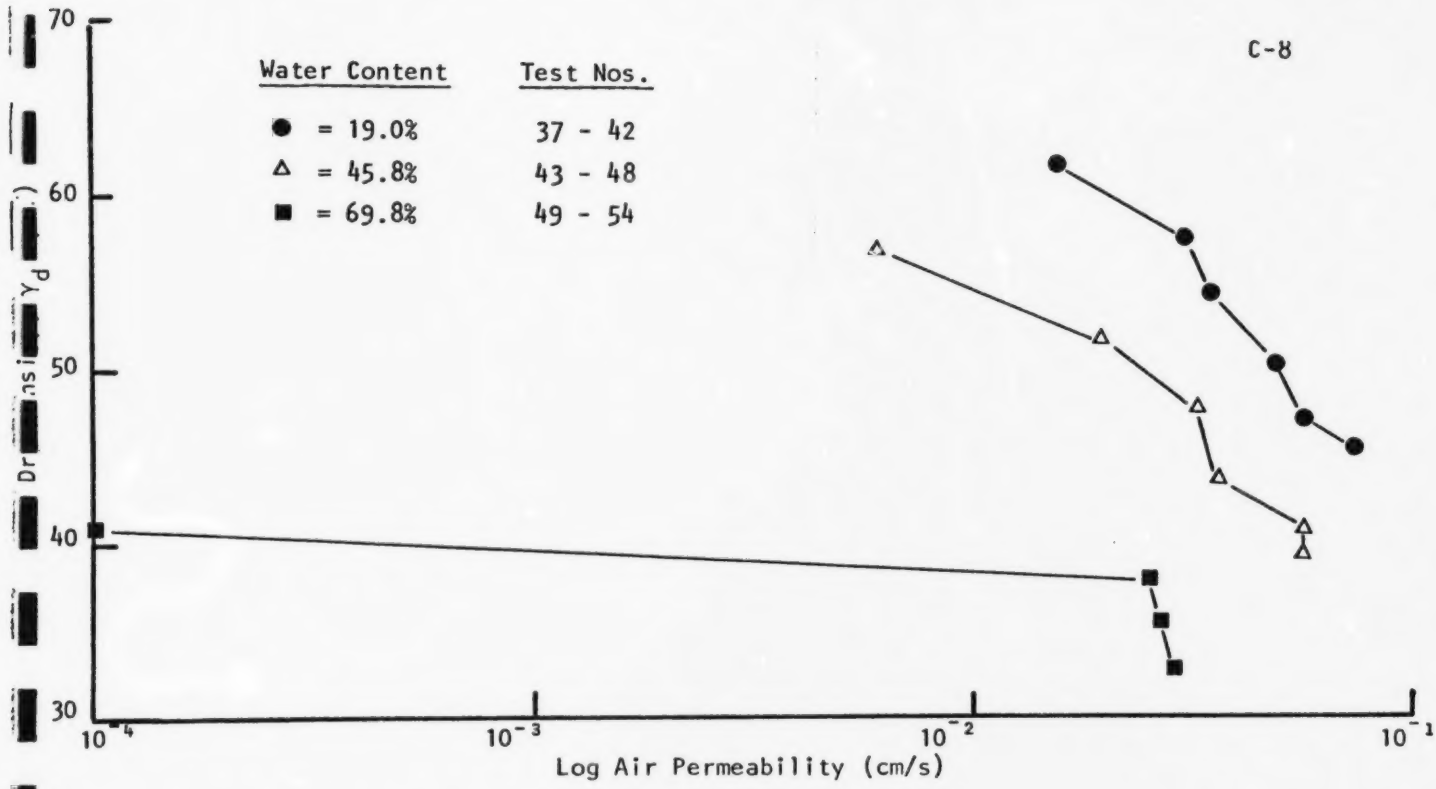

FIGURE NO. C-9: INFLUENCE OF THE DRY DENSITY ON THE AIR PERMEABILITY FOR SMALL, FINE, INCREMENTAL TESTS (1ST SERIES).

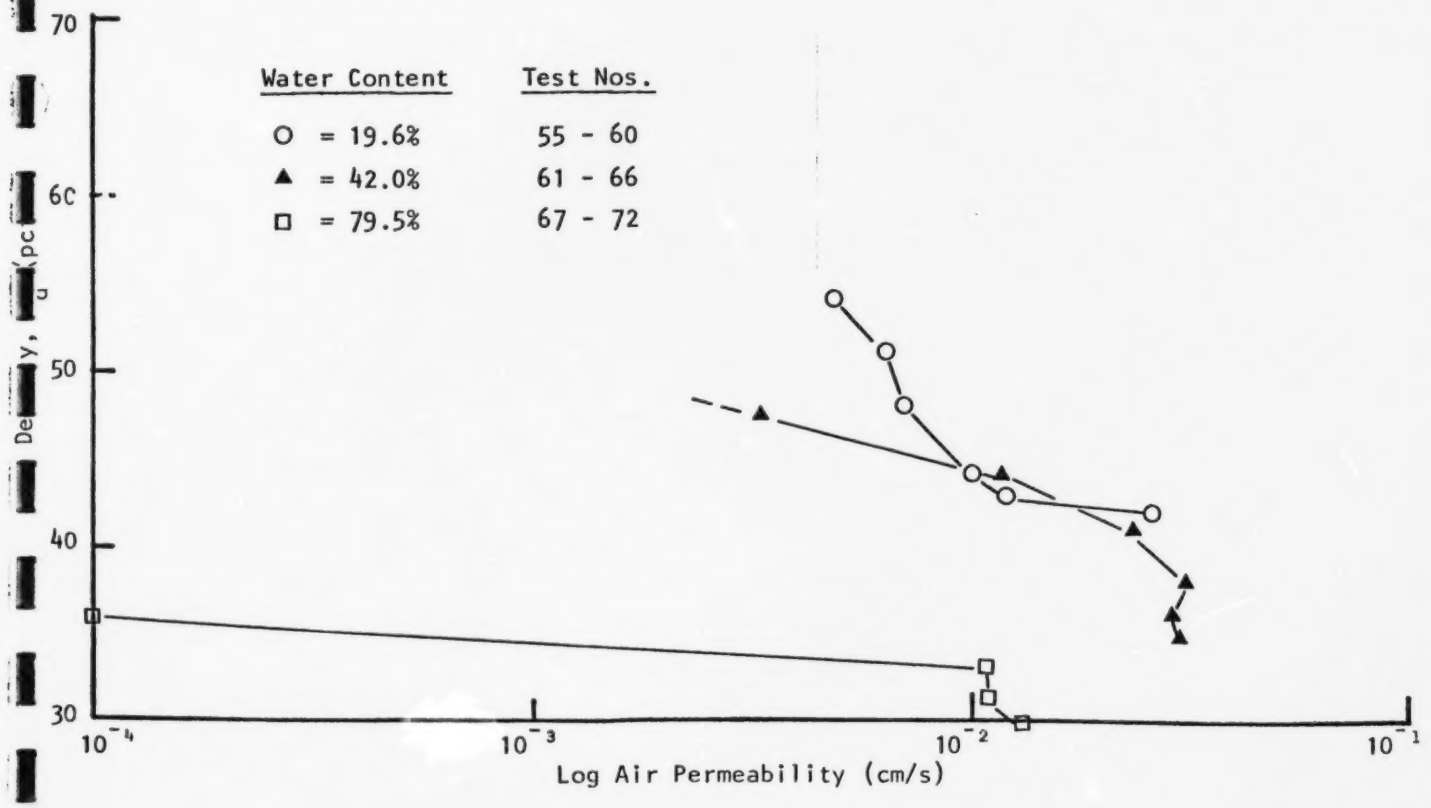

FIGURE NO. C-10: INFLUENCE OF THE DRY DENSITY ON THE AIR PERMEABILITY FOR SMALL, FINE, INCREMENTAL TESTS (2ND SERIES).

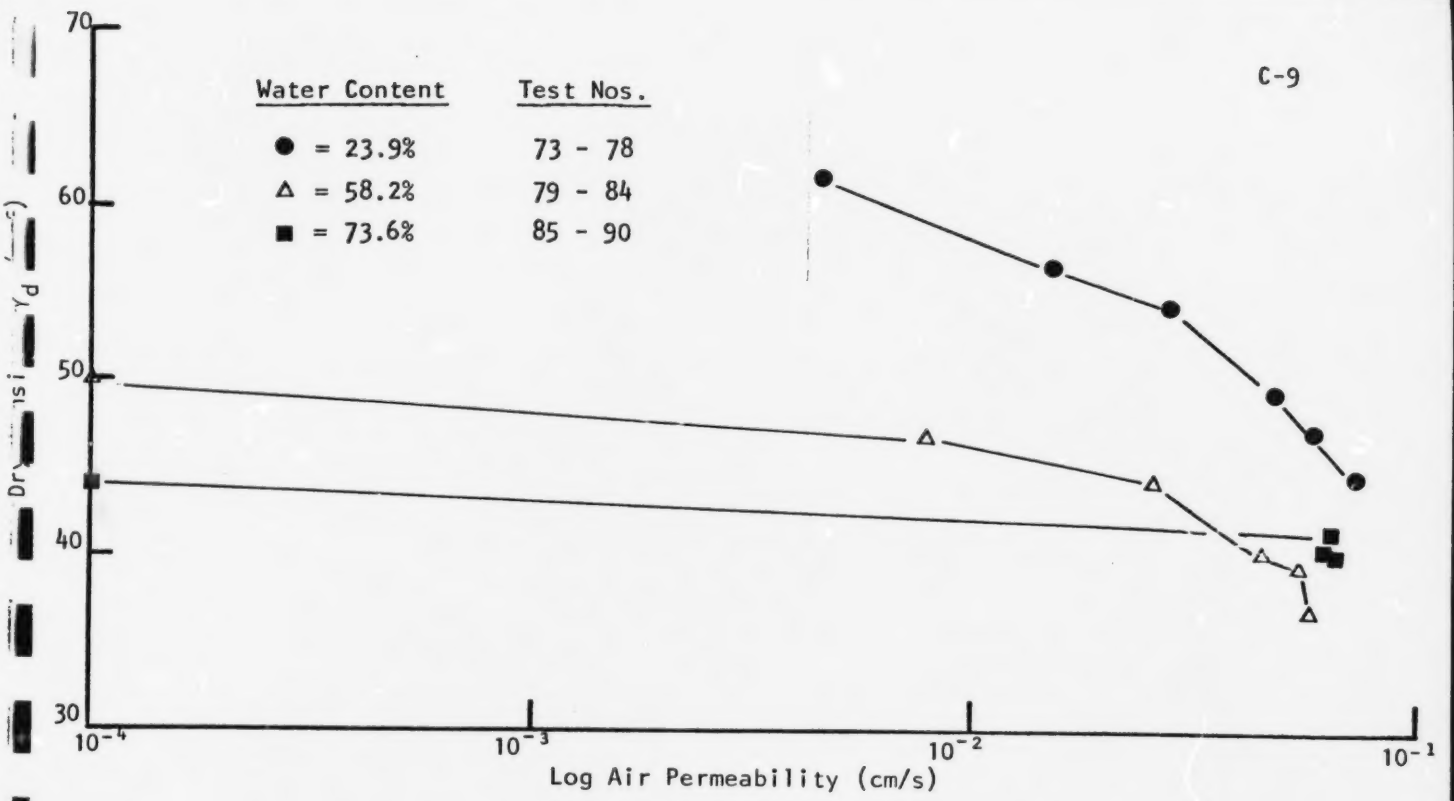

FIGURE NO. C-11: INFLUENCE OF THE DRY DENSITY ON THE AIR PERMEABILITY FOR SMALL, COARSE, INCREMENTAL TESTS (1ST SERIES).

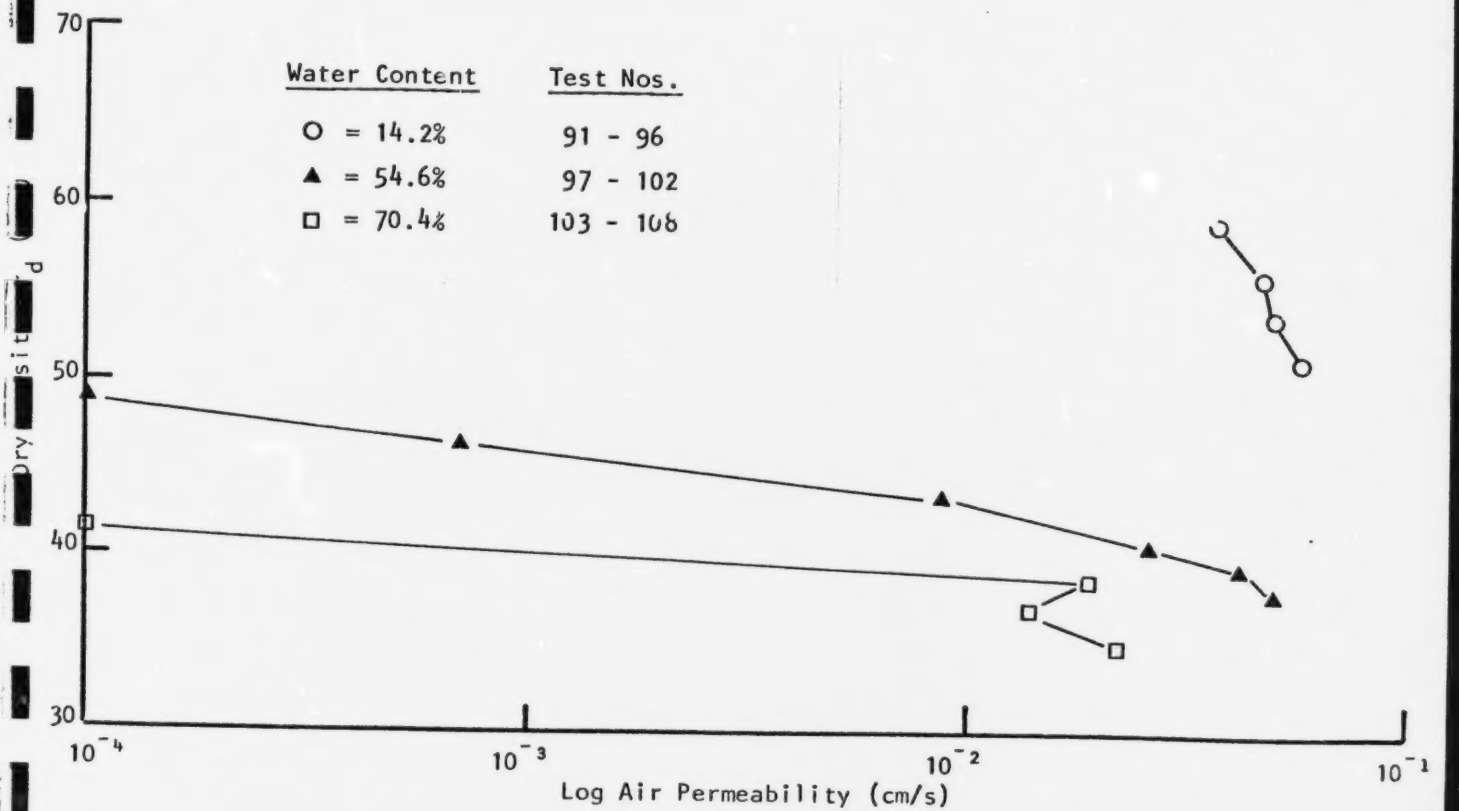

FIGURE NO. C-12: INFLUENCE OF THE DRY DENSITY ON THE AIR PERMEABILITY FOR SMALL, COARSE, INCREMENTAL TESTS (2ND SERIES).

POOR

QUALITY

ORIGINAL